State of Mississippi

Wastewater Treatment Facilities Operations and Training Manual

5th Edition

MISSISSIPPI DEPARTMENT OF ENVIRONMENTAL QUALITY

Prepared by
Office of Pollution Control, Field Services Division
Environmental Training and Certification

2007

STATE OF MISSISSIPPI

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WASTEWATER FACILITIES
OPERATIONS and TRAINING MANUAL
(5th Edition)

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Prepared For:

Mississippi Department of Environmental Quality
Office of Pollution Control
Environmental Training and Certification

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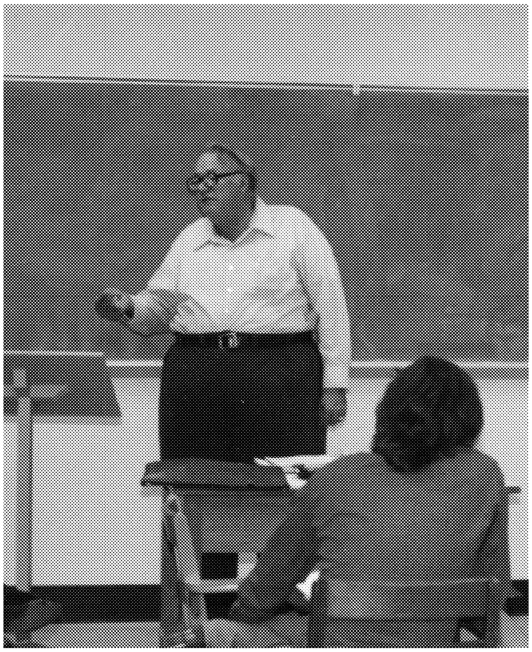
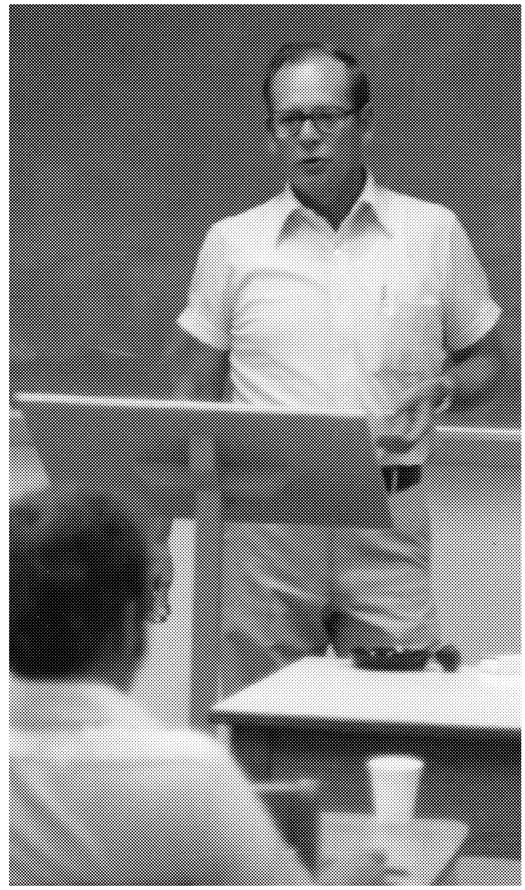
" THE BEGINNING"



Tom Anthony



Don Scott

OPERATOR TRAINING IN MISSISSIPPI

The Mississippi Department of Environmental Quality (MDEQ) has a proud history of providing effective training opportunities for operators of wastewater treatment facilities. The agency's training legacy began in 1969 when the newly created Mississippi Air and Water Pollution Control Commission started the State's first training program solely for wastewater personnel. Prior to the implementation of this program, virtually the only training available to wastewater operators was an annual week-long shortcourse held at Mississippi State University (MSU) in which combined classes were conducted for both water and wastewater personnel. Instruction for these combined classes were usually provided by the Mississippi State Department of Health and the Civil Engineering Department of MSU.

The initial program was funded with Federal money made available from the U.S. Department of the Interior and was highlighted by the hiring of Don Scott and Tom Anthony as full-time training instructors. The program was basically a six (6) month course which consisted of both classroom instruction and on-the-job training. Classroom sessions were scheduled at community colleges with Mr. Scott, Mr. Anthony, and college staff members providing the instruction. As a general rule, training in the northern areas of the State was conducted by Mr. Scott with Mr. Anthony doing the same in the southern areas.

In the early 1970's, the agency began using funds allocated by the State of Mississippi to provide training; and the program, as it exists today, really began to develop. Through the efforts of Mr. Scott and Mr. Anthony, a series of workshops covering a variety of topics were scheduled at various locations around the State. This coincided with the annual shortcourse at MSU being separated into two (2) separate courses for water and wastewater personnel. For the first time in Mississippi, a formal training program was designed and made available specifically for operators of wastewater treatment facilities. Training topics included math, hydraulics, biological treatment, and laboratory procedures. Instruction was largely provided by agency personnel and supplemented by volunteer instructors. Later, the curriculum was expanded to provide more comprehensive coverage of wastewater-related topics; and in the early 1980's, the annual MSU shortcourse was expanded to include a second companion course to be held annually on the Mississippi Gulf Coast.

With the adoption of operator certification regulations in 1987, MDEQ's role was somewhat changed to that of enforcement in addition to providing training. Today the agency continues to sponsor two (2) week-long shortcourses, numerous workshops, and on-site consultation to operators. In addition, many opportunities are now available through other training vendors. It should be remembered that the training opportunities available to today's wastewater operators are the result of the groundwork laid by Don Scott and Tom Anthony almost thirty (30) years ago. Because of their vision and efforts, the training opportunities available to operators in the State of Mississippi are acknowledged and respected nationwide.

PREFACE

The first edition of this manual was prepared in 1984 for the Bureau of Pollution Control of the Mississippi Department of Natural Resources. Compilation of the initial manual was a joint effort of certain personnel of the Bureau of Pollution Control and the firm of Engineering Service of Jackson, Mississippi, who was under contract to said Bureau. The principal author was W. Carroll Murphy, P.E. of Engineering Service whose primary tasks were development and preparation of the manuscript. Editors and contributing authors were Donald R. Scott, Thomas Anthony, Jr., Donald R. Cooley and Larry V. Murphree of the Bureau of Pollution Control.

In 1992, the Office of Pollution Control of the Mississippi Department of Environmental Quality contracted with the firm of Engineering Service of Jackson, Mississippi, to make certain revisions to the first edition of the manual. Under said contract, revisions were made to Chapters 3, 5, 7, 8, 12 and 13 of the manual. W. Carroll Murphy of Engineering Service was the principal author of the revised manuscripts. Donald R. Scott was sub-contracted by Engineering Service for the purpose of editing the revisions, compiling information and literature, and serving as a contributing author.

The compilation of the revised (second) edition of the manual involved the efforts of several persons in the employ of Engineering Service and the Office of Pollution Control. Special acknowledgment is due Phillip Bass, Larry Murphree, Nick Gatian, and Russell Lyons of the OPC for their technical assistance and editorial suggestions. Their availability throughout the compilation process is genuinely appreciated. Thanks are offered to Monica Motley of Engineering Service for her competent word processing of the entire manuscript; and to Frank Phillips and Tim Parker for their proofreading of same.

In 1996, Chapter 14, "Introduction to Wastewater Laboratory" was written and compiled by Phil Bass, Larry Murphree, Nick Gatian and Rusty Lyons of MDEQ/OPC as an addition to the second edition of the manual.

In 1998, the Office of Pollution Control contracted with W. Carroll Murphy of Engineering Service to author Chapter 15, "Facilities Management". This addition, and associated exam questions, were successful in MDEQ's efforts to gain full reciprocity with the Association of Boards of Certification's (ABC) highest level (Class IV) of certification.

The (4^{th}) edition of the **Mississippi Wastewater Facilities, Operations and Training Manual**, completed in 2001, contains very few revisions in the text, but does include new photographs. It has also been re-formatted to make it easier and less expensive to reproduce.

The latest (5^{th}) edition (2007) contains revisions to Chapter 6, Advanced Treatment, authored by W. Carroll Murphy , the original principal author of this manual. Chapter 15, Management, has also been updated to include information on emergency management in accordance with the National Incident Management System (NIMS) and site security measures.

A companion Study Guide consisting of quizzes for each chapter and practice math problems is available for those preparing for the Mississippi Pollution Control Operator Certification examination. To obtain an order form, visit the MDEQ website www.deq.state.ms.us or contact the regional Operator Trainer in your area.

The manual and study guide are also available on CD ROM. We hope to make any future changes and revisions available on the MDEQ website.

About the Author

W. Carroll Murphy, P.E.

Carroll was born in Port Neches, Texas and moved with his family to Mississippi at an early age following the passing of his father. Interestingly, Carroll's father had served as the Waterworks Superintendent for the City of Port Neches.

Carroll grew up in Petal and graduated from Petal High School. He graduated from Mississippi State University with a B.S. Degree in Civil Engineering in 1966. After graduating, Carroll began his career with the U.S. Army Corps of Engineers Waterways Experiment Station in Vicksburg. He went back to MSU and received his M.S. Degree in Environmental Engineering in 1968 and went to work for the newly created Mississippi Air and Water Pollution Control Commission in 1969.

Carroll began teaching prospective Pollution Control Operators at the Mississippi Water and Pollution Control Operator's Association Shortcourses at Mississippi State, while employed by the Commission. Carroll left the employment of the Commission in 1973 and started work with Engineering Service, Inc. in Florence, eventually becoming a principal in the firm. He continued to serve the Operator's Association as an instructor at the shortcourses until 1999, shortly before he became the Director of Engineering for the MS Band of Choctaw Indians.

Through all of his years of service, Carroll would never accept any compensation, including expenses, for himself, or his company, for his work at the Shortcourses.

Carroll has achieved many accomplishments and has received many awards during his career:

- Licensed as Professional Engineer and Land Surveyor in Mississippi, Alabama and Arkansas
- Mississippi Certified Pollution Control Operator
- Past President, Mississippi Water Pollution Control Association
- Founding Chairman, Mississippi Water Environment Association Outstanding Wastewater Treatment Facility Award Committee
- Chairman, Advisory Committee for Mandatory Operator Certification
- Outstanding Civil Engineering Student, American Society of Civil Engineers, 1966
- Meritorious Service Recognition (Howard K. Williford Award), Mississippi Water and Pollution Control Operator's Association, 1980
- Lifetime Membership, Mississippi Water and Pollution Control Operator's Association, 1989
- Water/Wastewater Diplomate, American Academy of Environmental Engineers, 1990
- Arthur Sidney Bedell Award, Water Pollution Control Federation, 1991
- Award for Outstanding Dedication, Mississippi Water and Pollution Control Operator's Association, 2000

Carroll's latest endeavor was in revising this 5th Edition of the training manual for the Mississippi Department of Environmental Quality that he originally authored in 1984. Again, Carroll would not accept any pay for this work.

Carroll and his wife Georgia now reside in Starkville (which is like living in Heaven to Carroll). It is an understatement to say that Carroll is an avid Mississippi State supporter. He and Georgia enjoy following all of the MSU sports teams.

Thanks, Carroll and Go Dawgs!

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Exhibits (continued)

LIST OF TABLES

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CHAPTER 1

INTRODUCTION AND USER GUIDE

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CHAPTER 1

INTRODUCTION AND USER GUIDE

1-1 PURPOSE OF MANUAL

The objective of wastewater collection and treatment is the removal of objectionable material contained therein from the environment and, by so doing, to create pollution-free conditions in our water and air resources. Accomplishing this objective will result in the prevention of nuisances and conditions which otherwise might be harmful or injurious to public health.

Wastewater is produced by man - thus, the responsibility for its collection and treatment must be borne by man. The treatment of wastewater is essentially an attempt by man to duplicate nature's processes for decay of organic matter under controlled conditions. There are numerous processes available for providing this treatment. This manual has been prepared to assist operators and others involved with the collection and treatment of domestic wastewater in gaining basic knowledge and information needed to efficiently and effectively achieve their objectives.

The manual is not intended to be a facility "Operation and Maintenance" manual. Instead, it is intended to serve as a reference source and compilation of basic principles and information which can be incorporated into the operational practices at a facility. Hopefully, it will provide guidance and instruction to those persons whose livelihoods depend on understanding and applying sound principles of wastewater treatment facility operations.

1-2 SCOPE OF MANUAL

The manual is intended to provide basic information on a broad range of topics related to the collection and treatment of domestic wastewater. The scope of topics includes the following:

1. Characteristics of Wastewater,
2. Treatment Processes,
3. Flow measurement,
4. Collection and Pumping Systems,
5. Records and Reports,
6. Safety,
7. Wastewater Laboratory, and
8. Management

The physical, chemical, and biological characteristics of domestic wastewater (sewage) are addressed in Chapter 2. Chapters 3 through 8 cover the various unit processes involved in wastewater treatment. These processes include preliminary treatment methods, primary treatment methods, biological treatment processes, advanced treatment processes, disinfection, and sludge treatment/disposal. The practice of measuring flows at a wastewater treatment facility is addressed in Chapter 9. Chapters 10 and 11 cover wastewater collection (sewers) and pumping systems respectively. Records and reports are the subject of Chapter 12; and Chapter 13 addresses safety in wastewater collection and treatment systems. An introduction to the wastewater laboratory is discussed in Chapter 14 and management issues are addressed in Chapter 15.

One area of concern which is noticeably, but necessarily, not addressed in the manual is equipment maintenance. Such a topic, while vital to wastewater operations, is considered to be beyond the scope of the manual because of the many and varied types of equipment available and the detail to which the manual would have to go in order to effectively address the topic. Instead, the manual assumes the position that manufacturers' literature should be consulted for guidance in equipment maintenance.

1-3 REFERENCES

During the preparation of this manual, numerous references were consulted. Listed in the Appendix are those references on which much of the technical material presented in this manual is based. Many of these references were consulted for several topics while others may have served as support material for single topics.

1-4 GLOSSARY

A glossary of common wastewater terms was compiled during the preparation of the manual and is presented in the Appendix.

CHAPTER 2

WASTEWATER CHARACTERISTICS

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CHAPTER 2

WASTEWATER CHARACTERISTICS

2-1 TERMINOLOGY

Once a community's water has been used for residential, commercial, industrial, and institutional needs, it generally is discharged into a sewer system and is referred to as "wastewater". In a municipal or community system, wastewater generally originates from domestic and industrial uses. Domestic wastewater is usually called "sewage" or "sanitary wastes" and is produced from such sources as restrooms, bathing, cooking, washing clothes, dishwashers, drinking fountains, etc. Industrial wastewater is discharged from manufacturing plants after being used in the manufacture of a product. The combination of a community's industrial wastewater and domestic wastewater, plus any groundwater infiltration or stormwater inflow which enters the sewer system is commonly called "municipal wastewater." In many smaller communities in which no industries are located, "municipal wastewater" is made up only of domestic wastewater and infiltration/inflow.

In this manual, only the characteristics of domestic wastewater, or sewage, will be discussed. The composition of industrial wastewater is highly variable and dependent on the specific manufacturing processes involved and is therefore beyond the scope of this manual. Domestic wastewater, on the other hand, is generally more consistent in its make-up due to the fact that it originates from human uses which vary little from community to community.

2-2 PHYSICAL CHARACTERISTICS

a. Temperature

The temperature of sewage is typically a few degrees higher than the water supply because of the addition of warm water from residential and industrial uses. Specific temperatures vary depending on the geographic location and characteristics of a community. In most cases, the temperature of sewage will vary from 10˚C to 21˚C (50˚F to 70˚F). A significant increase in the temperature of wastewater often indicates the presence of an industrial waste. Also a significant decrease in temperature many times indicates the presence of groundwater and/or stormwater.

b. Odor

Odors are generally of more concern to the public than any other wastewater characteristic. Most odors are caused by gases which are produced when bacteria and other microorganisms utilize the organic matter in wastewater as a food source. Odors normally can be categorized as either "fresh" or "septic". Fresh sewage has a distinctive musty odor which is slightly objectionable but not too offensive. Septic sewage on the other hand is normally very offensive with a hydrogen sulfide (rotten egg) odor. Septic sewage is void of oxygen; and anaerobic microorganisms produce the hydrogen sulfide while decomposing organic matter.

c. Color

The color of sewage varies depending on whether "fresh" or "septic" conditions exist. Fresh sewage is usually gray. As bacteria begin to break down the organic matter in sewage, the dissolved oxygen content is soon reduced to zero. When this occurs, septic conditions are created and the color changes to black. Colors such as red, green, yellow, etc. which might appear in wastewater normally indicate the presence of an industrial discharge.

d. Solids Content

Because wastewater is comprised of water which has been used for many purposes, it naturally contains a large quantity of solid matter. The term "solids" includes floating or suspended matter as well as solid matter which has been dissolved. From the standpoint of the physical condition in which solids exist, there are two types of solid matter in wastewater - suspended solids and dissolved solids. The sum of suspended and dissolved solids is referred to as total solids.

Any solids content, whether suspended, dissolved or total, normally has a certain portion which contains microorganisms or which can be used as food by microorganisms in biological treatment. This portion is organic and is referred to as volatile solids. The non-volatile portion which is inorganic or inert is called fixed solids. Normally the suspended solids in raw sewage are 60% to 80% volatile. Dissolved solids are typically 50% to 70% volatile.

Solids are typically measured in units of milligrams per liter (mg/l). Table 2-1 lists typical values of solids concentrations normally found in raw sewage.

TABLE 2-1

TYPICAL SOLIDS CONTENT

OF

RAW SEWAGE

	Concentration (mg/l)		
		Extremes	
Parameter	Normal Range	Low	High
Total Solids*			
Total	500 to 750	300	1,000
Volatile	320 to 475	190	750
Fixed	180 to 275	110	400
Dissolved Solids*			
Total	300 to 500	200	800
Volatile	180 to 300	120	500
Fixed	120 to 200	80	300
Suspended Solids*			
Total	200 to 250	100	350
Volatile	140 to 175	70	250
Fixed	60 to 75	30	100

*NOTE: Total Solids = Total Dissolved Solids + Total Suspended Solids

2-3 CHEMICAL CHARACTERISTICS

a. Organic Content

The pollution-causing component in sewage is organic matter. Organic matter is normally composed of a combination of carbon, hydrogen, and oxygen. Other important elements such as nitrogen, sulfur, and phosphorus may also be present. The main groups of organic substances found in wastewater are proteins, carbohydrates, fats and oils. Proteins are the principal components of all animal organisms. Carbohydrates are widely distributed in nature and include such common substances as sugars, starches, cellulose, and wood fiber. Fats and oils are compounds comprised of alcohol or glycerol with fatty acids. They are contributed to wastewater from such sources as butter, lard, margarine, and vegetable oils. Fats are also found in meats, seeds, nuts, and certain fruits. Petroleum products, which contain primarily carbon and hydrogen, many times are contributed to sewers from shops, garages, and streets.

The organic content of a wastewater can be measured by several different laboratory tests. The most common test is for 5-day biochemical oxygen demand (BOD_5), which is simply a measure of the amount of oxygen utilized by microorganisms for the biochemical stabilization of organic matter during a 5-day period at a temperature of 20˚C. Other tests which can be used to evaluate organic content include volatile solids, total organic carbon (TOC), chemical oxygen demand (COD), organic nitrogen, and oil/grease. Table 2-2 contains typical values of the organic content of raw sewage as measured by the aforementioned analyses.

TABLE 2-2

TYPICAL ORGANIC CONTENT

OF

RAW SEWAGE

Parameter	Concentration (mg/l) Normal Range	Extremes Low	Extremes High
5-Day Biochemical Oxygen Demand (BOD_5)	200 to 250	100	400
Total Organic Carbon (TOC)	150 to 175	80	300
Chemical Oxygen Demand (COD)	450 to 550	250	1,000
Volatile Solids			
Total	320 to 475	190	750
Dissolved	180 to 300	120	500
Suspended	140 to 175	70	250
Organic Nitrogen	15 to 20	5	40
Oil/Grease	80 to 120	50	150

b. pH

The pH of wastewater is important because biological treatment is difficult to achieve if the pH is not within an acceptable range. The pH of a substance is the concentration of hydrogen and hydroxyl ions and, as such, is a measure of how acidic or alkaline that substance is. The pH scale ranges from 1 to 14 with 7 being neutral. Values less than 7 are acidic and those greater than 7 are alkaline. The pH of a wastewater is influenced by the pH of the natural water supply as well as the purposes for which the water is used before being discharged as wastewater. Typically, the pH of raw sewage will be in the range of 6.5 to 8.5. When the pH of wastewater is less than 6 or greater than 9, operational problems are often experienced at the treatment facility which treats the wastewater.

c. Nitrogen

The element nitrogen is an essential ingredient in the growth of living organisms. In raw sewage, nitrogen normally exists as organic nitrogen and ammonia nitrogen. In most instances, the ratio will be about 60% ammonia and 40% organic. Organic nitrogen is usually quickly converted to ammonia nitrogen by the bacterial action which occurs in biological treatment processes. The sum of ammonia nitrogen and organic nitrogen is called total Kjeldahl nitrogen (TKN). Forms of nitrogen such as nitrite and nitrate normally do not exist to any noticeable degree in domestic wastewater. Table 2-3 contains typical concentrations of those forms of nitrogen usually found in raw sewage.

TABLE 2-3

TYPICAL NITROGEN CONTENT

OF

RAW SEWAGE

	Concentration (mg/l)		
		Extremes	
Parameter	Normal Range	Low	High
Total Kjeldahl Nitrogen (TKN)	35 to 45	20	85
Organic Nitrogen	15 to 20	5	40
Ammonia Nitrogen	20 to 25	15	45
Nitrate Nitrogen	0	0	Trace
Nitrite Nitrogen	0	0	Trace

d. Phosphorus

Phosphorus, like nitrogen, is essential to biological growth processes. Its presence in domestic wastewater is typically in a concentration range of 6 to 10 mg/l. Occasionally, the content may range as low as 3 to 4 mg/l and as high as 15 to 20 mg/l.

e. Gases

Raw sewage usually contains various amounts of such gases as nitrogen (N_2), oxygen (O_2), carbon dioxide (CO_2), hydrogen sulfide (H_2S), ammonia (NH_3), and methane (CH_4). Nitrogen, oxygen, and carbon dioxide are common atmospheric gases and are present due to exposure to air. Hydrogen sulfide, ammonia, and methane are present as a result of bacterial decomposition of the organic matter in wastewater.

f. Other Constituents

Other significant chemical constituents which are found in raw sewage include chlorides, sulfur, heavy metals, and toxic compounds. Chlorides originate from such sources as groundwater, household wastes, industrial wastes, and the natural content in a community's water. Chloride concentrations typically range from 40 to 60 mg/l in domestic wastewater, not including the amount naturally present in the domestic water supply.

Trace amounts of sulfur will be present due primarily to the natural content in the domestic water supply. Heavy metals and toxic compounds are frequently found in a community's wastewater in small amounts, and invariably can be found to originate from an industrial process. Examples of heavy metals which are frequently present include nickel, lead, chromium, cadmium, zinc, copper, iron, and mercury. Common toxic substances which are often discharged to sewers include phenols, acids, pesticides, and herbicides.

2-4 BIOLOGICAL CHARACTERISTICS

Wastewater generally contains organisms from each of the three (3) principal classes of living organisms: protista, plants, and animals. Protista includes such organisms as bacteria, algae, fungi, and protozoa. Plants associated with wastewater include ferns, mosses, liverworts, and seed plants. Animals commonly associated with wastewater are usually restricted to worms, rotifers, and crustaceans. The extent to which these various organisms exist in wastewater depends largely on whether or not the wastewater is treated or untreated. In raw sewage, the principal organisms present are bacteria. Bacterial counts in raw wastewater can be expected to range from 500,000/ml to 5,000,000/ml. Other organisms such as viruses, protozoa, and worms are often present, but their concentrations are usually negligible.

The bacteria present in raw sewage are primarily those which can live with or without oxygen and which require organic matter as a food source. Included in this group are disease producing bacteria called pathogens which originate in human and/or animal wastes. Pathogens in wastewater can cause such diseases as typhoid, dysentery, diarrhea, and cholera. Also, naturally present in wastewater are Fecal Coliform bacteria (E. Coli) which originate in the intestinal tract of warm blooded animals. These bacteria are not harmful to humans, but their presence indicates the possibility of pathogens. For this reason, the Fecal Coliform test is widely used, particularly on treated wastewater, as a measure of pathogen-free conditions.

2-5 SEWAGE QUANTITIES

The quantity of sewage contributed to a sewer system is influenced by the habits and practices of those who use the system. Exclusive of industrial wastes, the average wastewater discharge from domestic sources in most communities in Mississippi amounts to approximately 60 to 80 gallons per person per day. A higher figure of 100 gallons per day is commonly used for design purposes to allow for unknown conditions and groundwater infiltration. The flows contributed from industrial users vary considerably depending on the type and size of industry.

CHAPTER 3

PRELIMINARY TREATMENT

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CHAPTER 3

PRELIMINARY TREATMENT

3-1 ROLE OF PRELIMINARY TREATMENT

As wastewater leaves a sewer system and is discharged into a treatment plant, the first treatment normally provided is "preliminary" treatment or "pre-treatment" as it is often called. As the first step in the treatment of sewage, adequate preliminary treatment is necessary if a high quality effluent is to be produced. The overall performance of a plant is dependent on each component functioning properly as a complete system. If adequate primary treatment is not provided, the performance of all treatment components which follow will be less efficient; and the results will be an effluent of poorer quality. Except for lagoon systems, most sewage treatment facilities contain some type of preliminary treatment.

Preliminary treatment is a necessary first step in a wastewater treatment plant. Its role is to remove substances that would otherwise cause operational and/or maintenance problems with the major treatment processes in a plant. Substances typically removed by preliminary treatment include coarse solids (rags, garbage, metal, sticks, cans, plastic items, etc.,); sand and gravel; and oil and grease. Inadequate removal of such substances will usually produce one or more of the following conditions:

1. Interference with biological treatment,
2. Reduction in settling efficiency in clarifiers,
3. Interference with disinfection,
4. Increased maintenance problems with pumps and chain drives, and
5. Increased housekeeping problems.

Because of the lack of mechanical and moving parts, most lagoon systems typically do not contain preliminary treatment systems unless a specific need such as an industrial waste or an unusual wastewater characteristic requires the removal of certain substances ahead of the lagoon.

Preliminary treatment methods vary depending on the type and size of treatment plant and the characteristics of the wastewater being removed. Those methods commonly used in municipal wastewater treatment plants include:

1. Screening,
2. Comminution,
3. Grit Removal,
4. Oil and Grease Removal,
5. Pre-Aeration,
6. Flocculation,
7. Neutralization,
8. Chlorination, and
9. Flow Equalization.

Preliminary treatment facilities at a treatment plant may include any one or a combination of these methods. In addition other methods are often utilized to pretreat industrial wastewaters prior to their discharge to a sanitary sewer system.

3-2 SCREENING

Probably the most common preliminary treatment method utilized is a system of bar racks or screens. These devices serve to protect plant equipment by removing coarse matter such as rags, garbage, metal, sticks, cans, plastic items, etc. Removal of such substances prevents clogging of pipes, ports, weirs, orifices, nozzles, pumps, etc. and interference with moving parts such as chains, sprockets, shafts, wheels, etc.

Screens are usually classified as either "coarse" or "fine" based on the size of openings provided. A "coarse" bar screen consists of a rack of vertical or inclined steel bars spaced at equal intervals across a channel as shown in Exhibit 3-1. Spacings between bars typically range from 1-inch to 6-inches, with 1 to 2 inches being a common range for most municipal treatment plants. Bar screens with spacings larger than 2-inches are often inclined at an angle of 45° to 60°. Most systems are designed so that the velocity of flow as it enters the bar screen is in the range of 1 to 2 feet per second at average flow. Bar screens can be constructed for manual cleaning or installed with mechanical cleaning devices. Exhibit 3-2 shows mechanically cleaned screens.

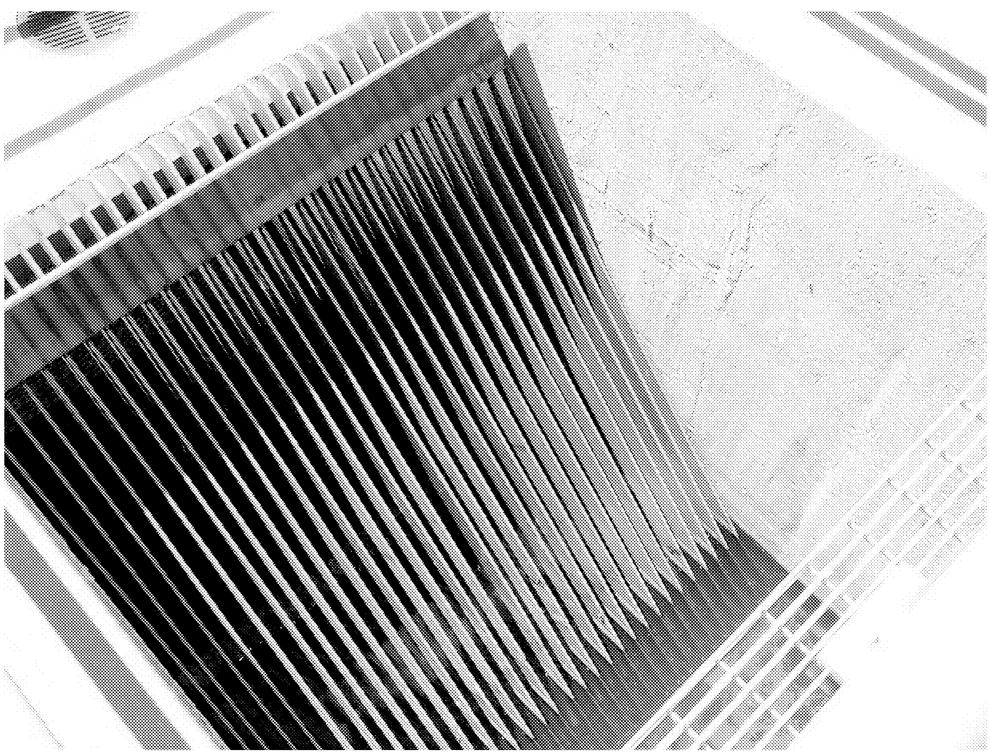


EXHIBIT 3-1

MANUALLY CLEANED BAR SCREEN

EXHIBIT 3-2

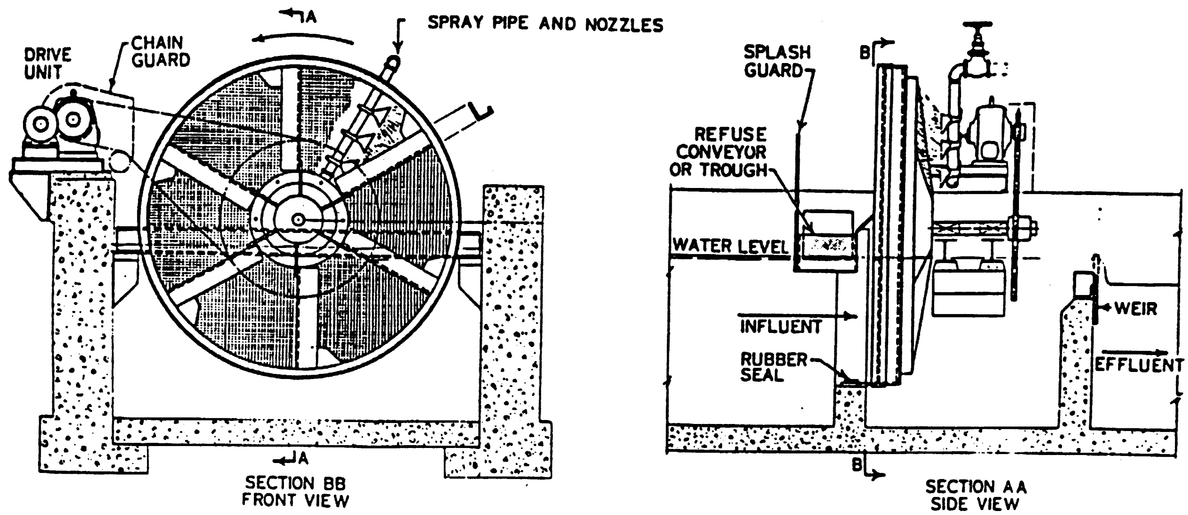
MECHANICALLY-CLEANED SCREENS

"Fine" screens usually have openings in the range of 0.009-inch to 0.126-inch (approximately 1/100th to 1/8th inch). Instead of bars, fine screens are often constructed of drums or discs. Disc screens usually consist of a vertical circular screening surface which rotates on a horizontal shaft. Drum screens are normally constructed to rotate on a horizontal axis with the drum partially submerged. Exhibit 3-3 illustrates disc and drum screens.

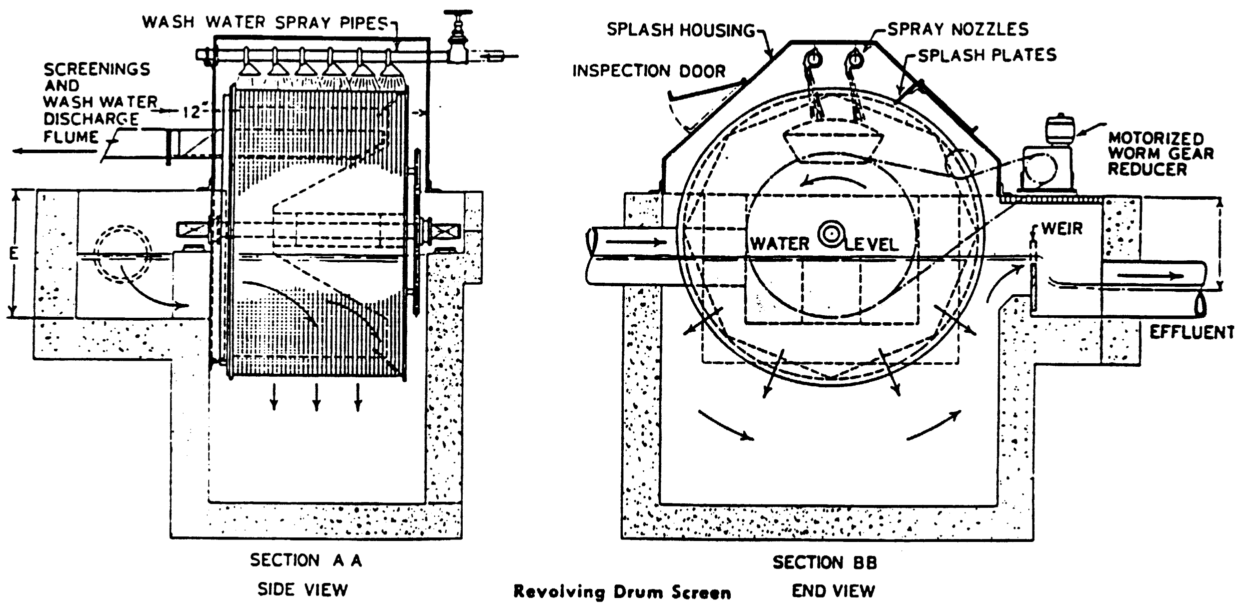
The material retained on screens is normally referred to as "screenings." This material must be removed from the screens and regularly disposed of in a satisfactory manner. Failure to remove screenings regularly and routinely can result in the following:

1. Velocity of flow through the screen will be reduced which will produce settling of solids in the approach channel and create odors.
2. Debris (screenings) will be pushed through the screen and flow to the next process.
3. Nuisance conditions from odors and insects will increase.

Screenings can be removed manually with a handrake or mechanically depending on the type of equipment installed. After removal from a screen, screenings are commonly placed in a closed container such as a trash can or similar container and then regularly disposed of by burying under a minimum of 6-inches of soil or placing in a landfill. Other disposal methods sometimes used include incineration and anaerobic digestion.



Revolving Disc Screen



Revolving Drum Screen

EXHIBIT 3-3

DISC AND DRUM SCREENS

SOURCE: FMC Corporation, Chicago, Illinois

The quantity of screenings collected by a screen is directly dependent on the size of the openings in the screen. For example, for typical coarse bar screens, the quantity of screenings usually varies from about 3 to 5 cubic feet per million gallons of sewage for 1-inch openings to about 1 to 2 cubic feet per million gallons for 2-inch openings. Obviously, more screenings will be retained by smaller openings than larger openings.

The composition of screenings is highly variable. Practically everything imaginable has been found on bar screens. Examples include commonly expected items such as cans, leaves, sticks, bricks, and rags as well as unexpected items such as false teeth, silverware, books, and money. Fecal matter is not a common component in screenings since it generally is contained in dissolved matter or fine solids. However, a large portion of screenings is organic in content and will decompose and produce odors. Screenings removed by coarse screens usually weigh about 60 pounds per cubic foot.

3-3 COMMINUTION

Comminutors or grinders are common devices located at sewage treatment plants. Their purpose is simply to shred or grind solid material into very small pieces and by so doing to produce two benefits for treatment processes which follow. First, shredding the large particles into small pieces prevents clogging of pumps, weirs, nozzles, orifices, chain drives, etc. Secondly, reduction of the size of particles makes the particles, many of which are organic in content, easier to treat. Shredded particles usually range in size from about ¼-inch to about ¾-inch. Exhibit 3-4 shows a typical comminutor. Comminutors are usually installed in parallel with a bar rack so that solids can be screened when the comminutor is out of service.

It is absolutely essential that comminutors be lubricated, adjusted and sharpened on a regular basis in strict accordance with the manufacturer’s recommendations. Care should be routinely taken to remove any grit or debris which might collect around a comminutor and reduce its cutting efficiency.

There are certain types of comminution devices which provide a combination of screening and cutting in a single device. Exhibit 3-5 depicts such a device.

3-4 GRIT REMOVAL

Such material as sand, gravel, cinders, egg shells, bone chips, coffee grounds, etc. is generally referred to as “grit.” Removal of this material from wastewater is highly desirable and usually results in the following benefits being produced:

1. Moving mechanical parts such as pump impellers and chain drives are protected from abrasion and wear.
2. Deposits of grit in pipelines, troughs, channels, hoppers, and tanks are reduced.
3. Frequency of cleaning tanks such as digesters, clarifiers, aeration basins, and chlorine contact basins is reduced.

There are numerous types of grit removal systems in use at wastewater treatment plants. The particular type of equipment installed is usually decided by the engineer who designs a plant. The two most common methods of grit removal are as follows:

EXHIBIT 3-4

COMMINUTOR

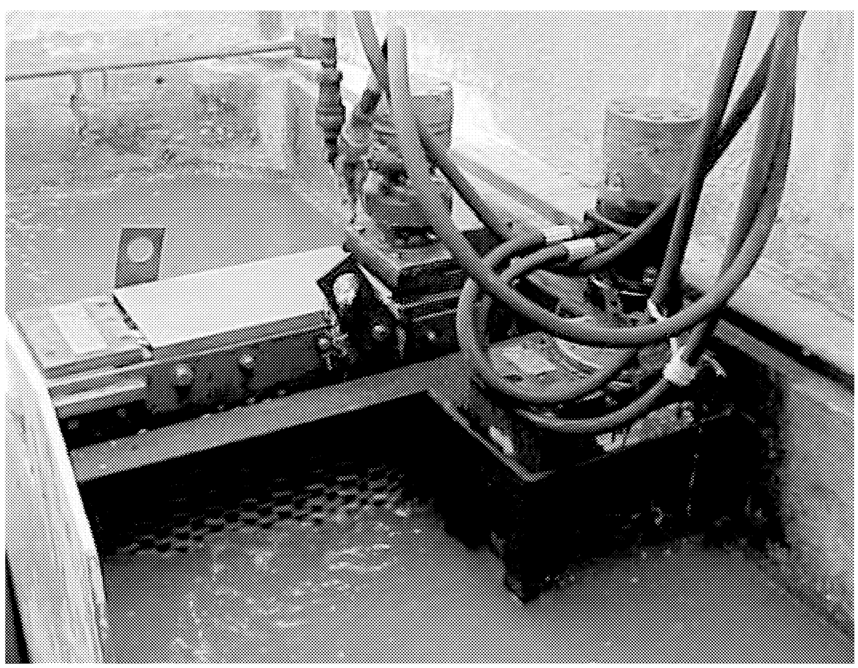


EXHIBIT 3-5

COMBINATION SCREENING AND COMMINUTION

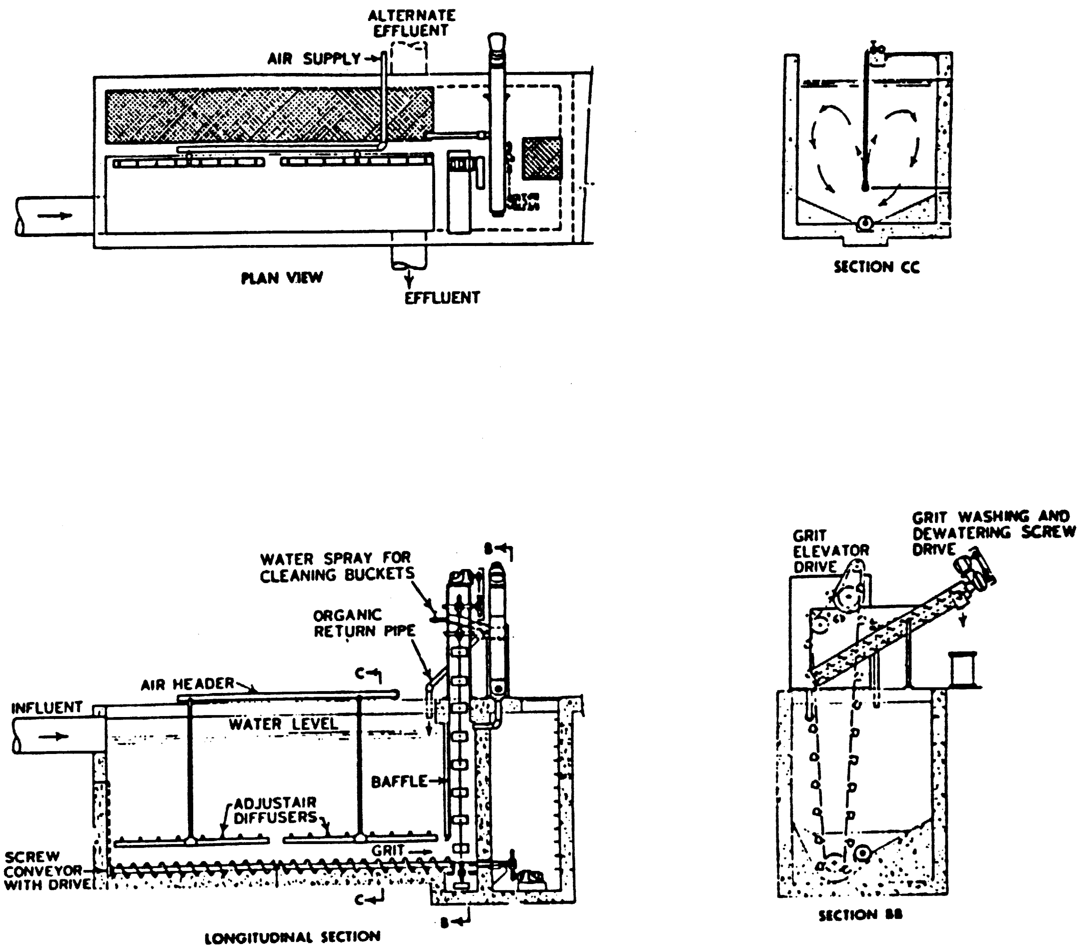


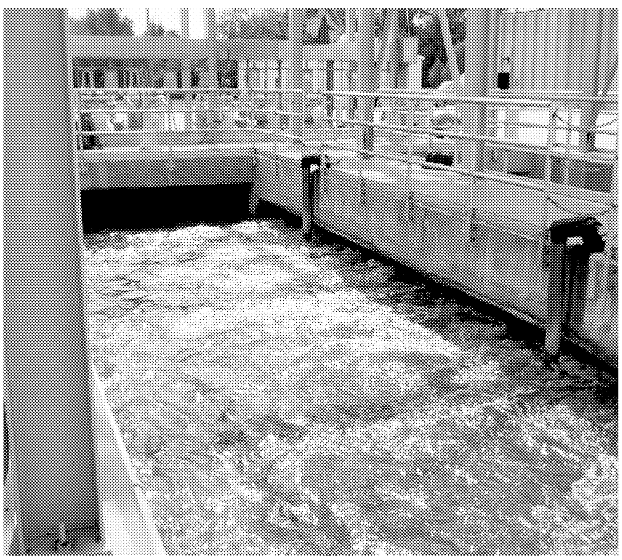
EXHIBIT 3-6

AERATED GRIT CHAMBER

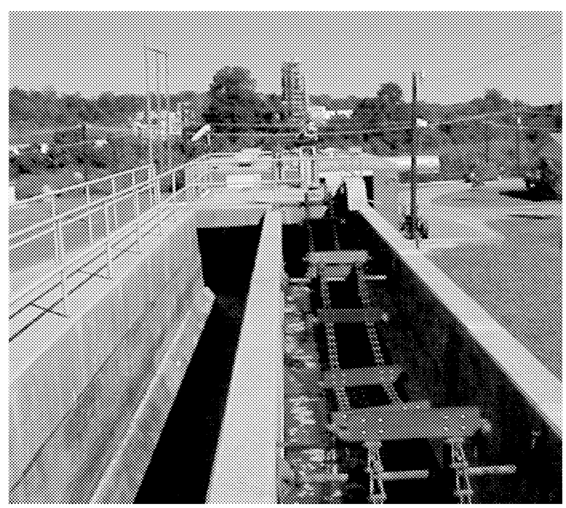
Source: FMC Corporation, Chicago, Illinois

1. Aerated Grit Chamber - This type system operates on a basis of utilizing air to create a spiral flow pattern in a tank. The velocity of the spiral flow is adjusted by controlling the quantity of air entering the tank. A velocity is maintained that will allow particles with a unit weight approximately equal to that of sand (Specific Gravity = 2.65) to settle. The grit removed by the spiral flow can be removed by various devices such as bucket assemblies, screw conveyors, or air lifts. Exhibit 3-6 shows the details of a typical aerated grit chamber.

2. Non-Aerated Grit Chamber - This type system operates on the basis of maintaining flow velocity in the range of 0.7 to 1.4 feet/second. An average velocity of 1.0 foot/second is usually the basis on which most systems are designed. At this velocity, all settleable matter with a unit weight approximately equal to that of sand (Specific Gravity = 2.65) will settle. At velocities significantly less than 1.0 foot/second, much of the organic matter will settle in the grit chamber instead of passing to the downstream biological treatment process. If the velocity is significantly greater than 1.0 foot/second, the "grit" will remain in suspension and not settle. The control of the velocity through the chamber is critical. Velocity is commonly controlled by such devices as Sutro proportional weirs or a Parshall flume located at the discharge end of the chamber. The actual chamber can be constructed in various shapes including rectangular and circular troughs. Grit which settles in the bottom of the chamber is normally removed manually or mechanically by either a bucket with chain drive or by screw conveyors. One of the most common types of non-aerated grit chambers is the horizontal flow channel illustrated in Exhibit 3-8.



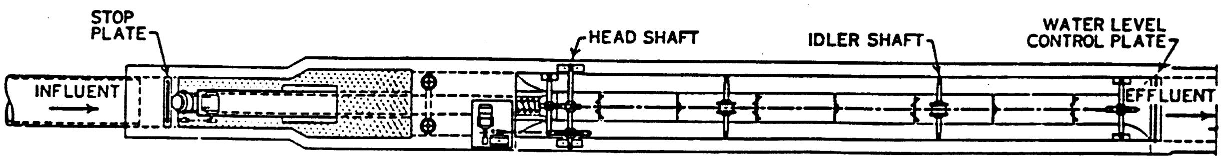
AERATED GRIT CHAMBER



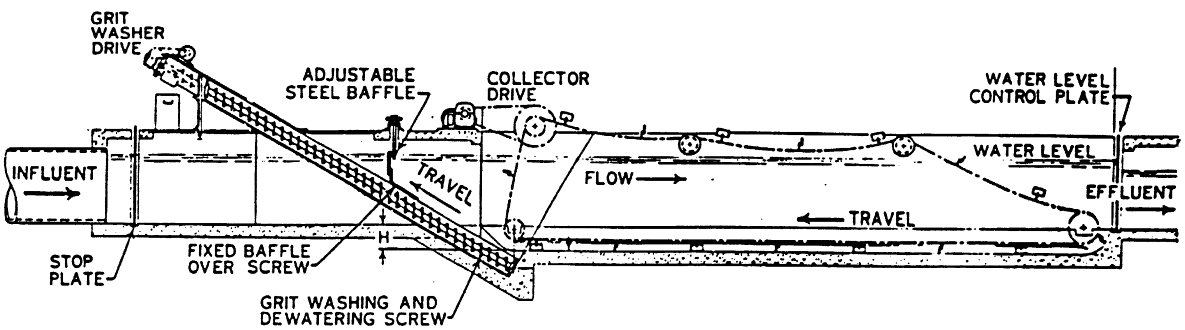
NON-AERATED HORIZONTAL FLOW GRIT CHAMBER

NON-AERATED CIRCULAR FLOW GRIT CHAMBER

EXHIBIT 3-7



PLAN VIEW



LONGITUDINAL SECTION

EXHIBIT 3-8

HORIZONTAL-FLOW GRIT CHAMBER

Source: FMC Corporation, Chicago, Illinois

When practical, grit removal units are normally located ahead of screens, comminutors, and pumps. However, many are sometimes located after influent pump stations at treatment plants because of the excessive depth required for installation ahead of the pumps.

The quantity and composition of "grit" varies greatly and is affected by the type and physical condition of the sewer system. Combined sewers which receive both sewage and storm water will naturally have large quantities of grit from the storm water. Similarly, a sanitary sewer in poor condition which experiences serious infiltration/inflow will receive larger quantities of grit than a system in good condition with minor I/I problems. The actual quantity removed at treatment plants varies considerably, depending on the characteristics and location of the sewers. The quantities may range from less than 1 cubic foot/million gallons of sewage to more than 15 cubic feet/million gallons. Factors which influence the composition of grit include types of street surface and maintenance frequency, size of area served, amount of storm water entering sewers, sewer grades, soil and groundwater conditions, quantity and characteristics of industrial wastes, and extent of use of household grinders.

Once grit has been removed from wastewater, it must be collected and disposed of in a safe and satisfactory manner to prevent odors and nuisance conditions. It is usually collected into a truck, trailer, or smaller container for transporting to the place of disposal. Sanitary landfill disposal or on-site burial is desirable when permitted. Other acceptable methods of disposal include lagooning and land spreading. Odors can be produced when lagooning or land spreading is used unless the grit contains less than 2% to 3% organic matter. Exhibit 3-9 shows various facilities for collecting grit for final disposal.

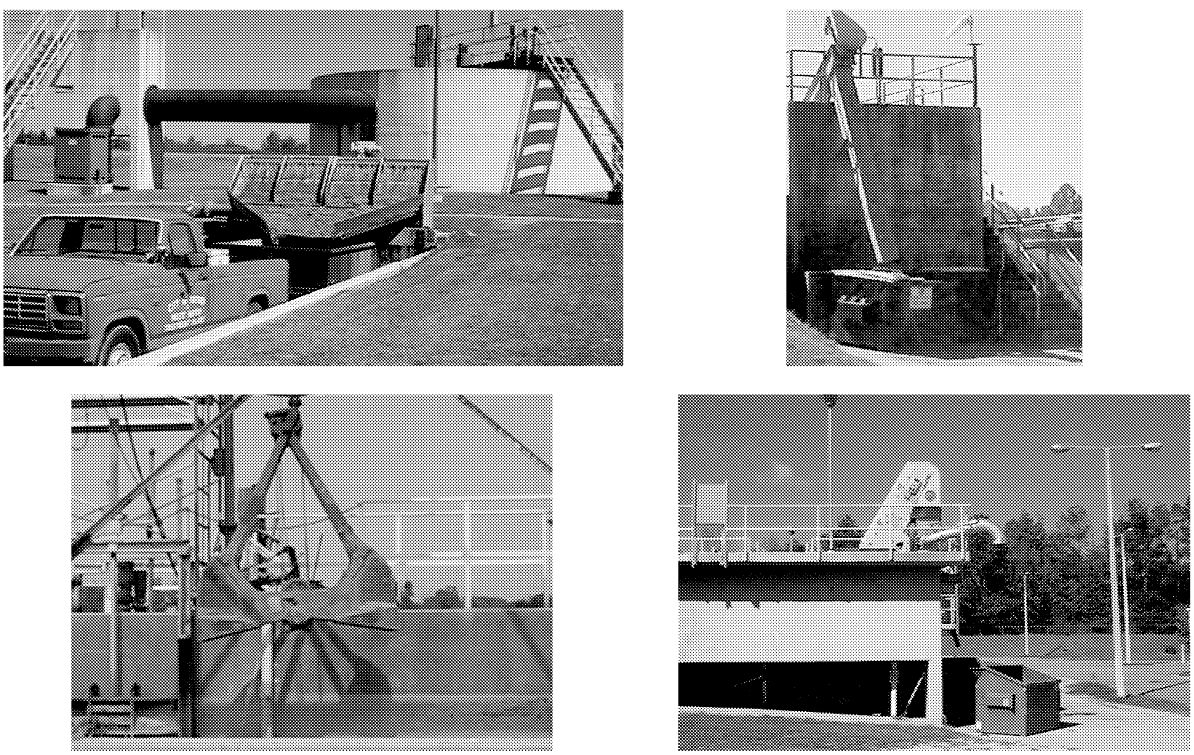


EXHIBIT 3-9

COLLECTION OF GRIT FOR FINAL DISPOSAL

3-5 OIL & GREASE REMOVAL

Oil and grease in excessive amounts can coat microorganisms, thereby interfering with biological treatment and creating nuisance conditions for operational personnel. It is generally estimated that 1 mg/l of oil and grease is equal to a 5-day BOD of 2 mg/l. Therefore, if the wastewater entering a treatment facility contains large amounts of oil and grease, it is common to install removal facilities as preliminary treatment ahead of a biological process. Most sewer ordinances require oil and grease concentrations to not exceed 100 mg/l. When values are expected to exceed the requirements of a community's sewer ordinance, oil and grease removal should be included as a part of preliminary treatment.

Commonly used methods of oil and grease removal in municipal systems include:

1. Grease Traps - These devices consist of small skimming tanks located at or near the source of oil and grease. Common sources include cafeterias, hospitals, and industries. In these systems, the oil and grease is allowed to float to the top after a detention of about ten (10) to thirty (30) minutes. The flow then leaves the trap from below the surface free of significant amounts of oil and grease.
2. Skimming Tanks - Skimming tanks operate on virtually the same principle as grease traps, which is to provide conditions where the oil and grease will float to the surface. However, these units are larger and usually located at the treatment plant. They are sized for typical detention times of one (1) to fifteen (15) minutes. Skimming devices are installed to skim the collected oil and grease from the surface. Flow, free of significant amounts of oil and grease, leaves the skimming tank from a deep outlet protected by baffles.
3. Air Flotation - This method is a process of removing oil and grease by using finely diffused air to float oil and grease particles to the surface. Once collected on the surface, the oil and grease is removed by skimmers. This system is commonly used by industries or at treatment plants when larger quantities of oil and grease are normal.

Oil and grease removed from grease traps can be disposed of by burying or placing in a sanitary landfill when permitted. Oil and grease removed at treatment plants are typically placed in a digester.

3-6 PRE-AERATION

Occasionally a need will arise at a wastewater treatment facility in which it becomes necessary or desirable to aerate the raw wastewater ahead of the major treatment process. This can be done at the treatment facility or within the collection system. Such preliminary treatment is called "pre-aeration;" and it simply involves injecting air into the influent at some point ahead of the major treatment processes. Usually, pre-aeration is provided to freshen septic wastewater and thereby produce the following benefits:

1. Prevent septicity and odors,
2. Improve uniform distribution of suspended and floating solids, and
3. Improve treatability.

3-7 FLOCCULATION

Flocculation is a process in which certain chemicals called flocculants are added to wastewater to improve its settling characteristics. The flocculants cause the settleable particles to join together to form "flocs" which are heavy enough to settle. Common chemicals used in flocculation processes include alum, lime, ferric chloride, and polymers.

Flocculation is usually used as a preliminary treatment method at municipal treatment plants when one or more of the following conditions exist:

1. Characteristics of wastewater is such that poor settling occurs in the primary and/or secondary clarifiers.
2. A need exists to increase settleability ahead of biological treatment to remove solids in heavy industrial wastes.
3. A need exists to simply improve the overall efficiency of a plant with a heavy organic load.

The chemicals must be injected into the wastewater in a well-mixed state so that the flocculation process will be adequately distributed. Usually, a mixing device such as a chemical feed flash mixer, air jet, or paddle wheel is used.

3-8 NEUTRALIZATION

The pH of a wastewater can be a critical factor in the performance of a wastewater treatment facility. Extreme pH values can seriously upset biological treatment processes. When the wastewater contains only sewage and infiltration/inflow, the pH is typically in a reasonably neutral range and needs no preliminary adjustment prior to treatment. However, if certain types of industrial wastes are present, the pH may need adjustment either at the source of the industrial wastewater discharge or at the treatment plant. In most instances, the adjustment should occur at the source of the waste discharge into the sewer system.

Neutralization is the addition of a chemical to adjust the pH of a wastewater to a reasonably neutral value. A pH of 7.0 is exactly neutral - it is not too acidic or too alkaline. The basic purpose of neutralization is usually to adjust the pH to as near 7.0 as is practical, or at least to within an acceptable range as allowed by a community's sewer use ordinance. Chemicals used to neutralize a wastewater depend on the direction of pH adjustment needed. If the pH is low, an alkaline substance will be needed to raise the pH. Conversely, an acidic substance will need to be added if the pH is high.

3-9 CHLORINATION

Chlorination is a process normally associated with effluent disinfection following biological treatment. However, occasionally a need arises for chlorination ahead of the major treatment process in a plant. The use of chlorine in this manner is often referred to as "pre-chlorination." It is usually used to help control oil and grease, odors, corrosion, or slime growths. The point of application varies with the purpose of the chlorination, but it generally involves the injection of a chlorine solution into the wastewater just as in effluent disinfection. Pre-chlorination must be carried out very carefully by experienced personnel because excessive dosages can destroy the microorganisms so vital to a biological treatment process.

3-10 FLOW EQUALIZATION

Shock hydraulic loads caused by sudden and severe variations in flow can upset biological treatment processes and reduce treatment efficiencies. In systems which experience severe inflow problems, the flow through a plant may exceed average daily flow by several times during heavy rainfalls. To offset the effect of extreme flows, “flow equalization” can be used to dampen or “smooth out” peak flows.

Flow equalization is usually achieved at the head of a plant by using a storage tank, basin, or pond to receive the larger volumes of flow. The stored flow is then released to the main treatment processes gradually so that a more constant rate of flow is achieved. By equalizing the flow in this manner, hydraulic overloading is prevented and a more efficient treatment process is produced.

3-11 SEWER USE ORDINANCE

Although it can not be technically classified as a “preliminary treatment” method, a properly written and strictly enforced sewer use ordinance can do much in the “preliminary” stages of wastewater collection and treatment to assure that a treatment facility can perform in an efficient manner. It does this by restricting the quantity and quality of substances placed in a sewer system. A strictly enforced sewer ordinance can eliminate the need for certain preliminary treatment facilities at a community’s treatment plant simply by preventing certain substances from being placed in the sewer or by limiting the quantity and/or concentration of that substance. A sewer ordinance is particularly effective in controlling industrial wastes that are discharged to a community sewer system.

Examples of substances prohibited from being placed in a sanitary sewer system by a typical municipal sewer ordinance are as follows:

1. Any liquid or vapor having a temperature higher than 150˚F (65˚C).
2. Any water or wastes containing fats, wax, grease, or oils, whether emulsified or not, in excess of one hundred (100) mg/l or containing substances which may solidify or become viscous at temperatures between 32˚F and 150˚F (0 and 65˚C).
3. Any waters or wastes containing strong acid, iron pickling wastes, or concentrated plating solutions whether neutralized or not.
4. Any waters or wastes containing iron, chromium, copper, zinc, and similar objectionable or toxic substances; or wastes exerting an excessive chlorine requirement, to such degree that any such material received in the composite sewage at the sewage treatment works exceeds the limits established for such materials.
5. Any waters or wastes containing phenols or other taste-or odor-producing substances, in such concentrations exceeding limits which may be established as necessary, after treatment of the composite sewage, to meet the requirements of the State, Federal, or other public agencies of jurisdiction for such discharge to the receiving waters.
6. Any radioactive wastes or isotopes of such half-life or concentration as may exceed limits established in compliance with applicable State or Federal regulations.
7. Any waters or wastes having a pH in excess of 9.0 or less than 5.5.
8. Any waters or wastes having a BOD in excess of 350 mg/l.
9. Any waters or wastes having a suspended solids content in excess of 400 mg/l.
10. Any waters or wastes having a total Kjeldahl nitrogen content in excess of 50 mg/l.

11. Materials which exert or cause:
    a. Unusual concentrations of inert suspended solids (such as, but not limited to, Fullers earth, lime slurries, and lime residues) or of dissolved solids (such as, but not limited to, sodium chloride and sodium sulfate).
    b. Excessive discoloration (such as, but not limited to, dye wastes and vegetable tanning solutions).
    c. Unusual BOD, chemical oxygen demand, or chlorine requirements in such quantities as to constitute a significant load on the sewage treatment works.
12. Waters or wastes containing substances which are not amenable to treatment or reduction by the sewage treatment process employed, or are amendable to treatment only to such degree that the sewage treatment plant effluent cannot meet the requirements of other agencies having jurisdiction over discharge to the receiving waters.

Most ordinances establish fines and/or imprisonment for failure to comply with its requirements. An ordinance is only as good as its enforcement. Model sewer use ordinances are available from the Office of Pollution Control and from municipal attorneys and consulting engineers.

3-12 INDUSTRIAL WASTEWATER

In addition to the previously mentioned preliminary treatment methods commonly used at municipal wastewater treatment facilities, there are numerous other methods utilized for “pre-treatment” of industrial wastewaters. Preliminary treatment of industrial wastewater typically takes place at the industry prior to discharge to the municipal or publicly-owned sewer system. The objective of such preliminary treatment is usually to produce an effluent whose characteristics comply with the requirements of a sewer use ordinance and/or effluent limitations set forth in a NPDES permit issued to the industry. The numerous methods utilized in the pre-treatment of industrial wastewater vary widely depending upon the type of industry. While such methods are beyond the scope of this manual, it is important that persons with operational responsibilities at wastewater treatment facilities be aware of the basic regulatory requirements which govern the preliminary treatment of industrial wastewaters discharged into their systems.

In the State of Mississippi, the Office of Pollution Control (Department of Environmental Quality) regulates the preliminary treatment of industrial wastewaters. NPDES permits similar to those issued to publicly-owned treatment facilities are issued to industries which are classified as “significant industrial users” according to regulations of the U. S. Environmental Protection Agency. Said regulations, copies of which can be obtained from the Office of Pollution Control, currently define a significant industrial user of a publicly-owned sewerage system as either of the following:

1. All industrial users subject to the U.S. Environmental Protection Agency’s Categorical Pretreatment Standards under 40 CFR 403.6 and 40 CFR, Chapter I, Sub-Chapter N; or
2. Any industrial user that discharges an average of 25,000 gallons per day or more of process wastewater to a publicly-owned treatment facility (exclusive of sanitary, non-contact cooling and boiler blowdown wastewater); contributes a process wastestream which makes up five percent (5%) or more of the average dry weather hydraulic capacity or organic capacity of a publicly-owned treatment facility; or is designated by the Office of Pollution Control as having reasonable potential for adversely affecting the operation of a publicly-owned treatment facility or for violating any pre-treatment standard or requirement.

In addition to pre-treatment requirements which are set forth in permits issued to significant industrial users, there are certain standards which apply to all industries that discharge wastewater to a publicly-owned treatment facility, including industries who are not required to have a pre-treatment permit. Such standards prohibit the discharge of the following to a publicly-owned treatment facility:

1. Pollutants which create a fire or explosion hazard including, but not limited to, wastestreams with a closed cup flashpoint of less than 140 degrees Fahrenheit or 60 degrees Centigrade;
2. Pollutants which will cause corrosive structural damage, but in no case discharges with pH lower than 5.0, unless the treatment facility is specifically designed to accommodate such discharges;
3. Solid or viscous pollutants in amounts which will cause obstruction to flow and interference with the performance of the treatment facility;
4. Any pollutant, including oxygen demand substances, released in a discharge at a flow rate and/or concentration which will interfere with the treatment facility's performance;
5. Heat in amounts which will inhibit biological activity in the treatment facility, but in no case heat in such quantities that the temperature at the treatment facility exceeds 40 degrees Centigrade (104 degrees Fahrenheit) unless the Office of Pollution Control, upon request of the treatment facility, approves alternate temperature limits;
6. Petroleum oil, nonbiodegradable cutting oil, or products of mineral oil origin in amounts that will cause interference with or pass through the treatment facility;
7. Pollutants which result in the presence of toxic gases, vapors, or fumes within the treatment facility in a quantity that may cause acute worker health and safety problems; and
8. Any trucked or hauled pollutants, except at discharge points designated by the treatment facility.

It is important for anyone who is responsible for the operation of a wastewater treatment facility to be aware of any industrial wastewater discharges to the facility and the pre-treatment standards which the industry may be required to meet. Pre-treatment of industrial wastewater should be considered a vital component of the overall process of a wastewater treatment facility like any other preliminary treatment method. The performance of industrial pre-treatment systems should be monitored and expectations for effective operation should be no less than those for a system-wide treatment facility.

CHAPTER 4

PRIMARY TREATMENT

* * * * *

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CHAPTER 4

PRIMARY TREATMENT

4-1 PURPOSE OF PRIMARY TREATMENT

The purpose of "primary" treatment is to remove settleable and floatable matter from wastewater. This purpose is generally achieved in a facility known as a primary "clarifier" or settling tank. Two processes occur in a primary clarifier - sedimentation and skimming. Sedimentation is simply the process of settleable matter settling by gravity to the bottom of the clarifier. Skimming is the process of removing floating grease, scum and similar matter from the surface of the wastewater.

In the first half of this century, it was not uncommon to see sewage treatment plants which consisted only of primary treatment facilities. In recent years, however, primary treatment has been declared inadequate as the sole means of treatment and is now utilized as a component process ahead of certain secondary treatment processes. Primary clarifiers are normally located after preliminary treatment and ahead of the major secondary process. Trickling filters virtually always have primary clarifiers ahead of them, whereas other secondary processes such as activated sludge and aerated lagoons seldom require primary treatment. Primary clarifiers ahead of aeration tanks in activated sludge plants are not uncommon, but their existence is optional depending on cost considerations and the characteristics of the wastewater being treated.

As stated, the purpose of primary treatment is to remove settleable and floating matter from wastewater. Removal of this matter benefits the secondary treatment processes which follow a primary clarifier and results in a higher quality effluent. Specific benefits which are produced by having a primary clarifier ahead of a secondary treatment process include the following:

1. The organic load on the secondary process is reduced. A primary clarifier which is properly designed, operated, and maintained will usually remove 25% to 40% of the BOD_5 and 50% to 65% of the suspended solids in typical raw sewage.
2. Operational and housekeeping problems are reduced with trickling filters because of the removal of solids that otherwise could clog filters and distribution systems and thereby create ponding and excessive sloughing.
3. In activated sludge systems, primary clarifiers also serve to reduce the amount of energy required for mixing and treatment in the aeration basin by removing much of the solids from the raw wastewater.
4. Housekeeping and maintenance problems are reduced in such facilities as final clarifiers and chlorine contact tanks because large amounts of the heavier solids and floating matter have been removed in the primary units.

4-2 SEDIMENTATION

The major process which occurs in a primary clarifier is sedimentation or settling. This process results in the removal of settleable solids from the wastewater entering a primary clarifier. As long as wastewater is flowing through sewers or being pumped through force mains, it should be moving at a velocity high enough to keep solids in suspension. Sedimentation is achieved in a clarifier because the tank is large enough to create quiescent, or very still, conditions where the flow-through velocity is extremely low. Under such conditions, the settleable solids will settle by gravity to the bottom of the clarifier.

The solids which settle in a primary clarifier are both organic and inorganic in content. The solids which settle are usually referred to as “settleable solids.” The settleable solids which are collected in a primary clarifier usually are comprised of the natural contents of wastewater which range from the organic matter in sewage to the grit contributed by infiltration/inflow. These primary settleable solids differ considerably from those collected in a secondary clarifier which are mainly comprised of materials which have been converted to settleable solids by biological or chemical processes.

The following are factors which influence the settling of solids in a clarifier:

1. Sewage Characteristics - A strong or more concentrated wastewater will settle more readily than a weak wastewater. Also, fresh wastewater will settle more readily than septic wastewater because the biological decomposition which takes place under septic conditions reduces the size of solids and releases gases which tend to make solids float.
2. Weight of Solids - Solids with a higher unit weight will settle more rapidly than lighter solids. Weights of solids are usually expressed in terms of their “Specific Gravity” which compares the weight to that of water (62.4 pounds/cubic foot or 8.34 pounds/gallon). A specific gravity of 2.65 means that the substance is 2.65 times heavier than water.
3. Size and Shape of Solids - Solids with a large surface area in relation to their weight settle very slowly. Irregular-shaped particles settle more slowly than regular-shaped particles.
4. Detention Time - Detention time is important because the settling efficiency depends on the velocity of flow through the clarifier. As the detention time increases, the velocity is reduced and the amount of solids which settle increases.
5. Inlet and Outlet Structures - The inlet should be baffled properly so that the entrance velocity is reduced and the flow uniformly distributed. The outlet structures should be baffled ahead of the overflow weirs to prevent solids and scum from leaving the clarifier.
6. Temperature - Warm weather will increase the biological activity within a sewer and thereby increase the possibility of septic wastewater being received at the treatment plant. Also, fresh wastewater in warm weather settles more readily than in cold weather due to the viscosity of the water. Settling in a water temperature of 80˚F will occur at approximately a 50% faster rate than when the temperature is 50˚F.
7. Chemicals - When needed, chemicals can be used to improve settling in a clarifier. This process is called flocculation (See Chapter 3, Preliminary Treatment) and utilizes such chemicals as alum, ferric chloride, and polymers to cause the solids to coagulate and form “flocs” which are heavier and thus settle faster.

4-3 SKIMMING

Under the quiescent conditions produced in a clarifier, a significant amount of grease-like materials will float to the surface where it can be skimmed off and removed. This process of removing floating matter is commonly called “skimming” and is a basic part of primary clarifiers. Skimming is normally achieved by slowly moving mechanical arms which literally skim the water surface and rake the floating matter into a trough or by air-suction devices which cause the surface contents to be vacuumed into a removal pipe.

Examples of floating materials which collect on the water surface in a clarifier and are removed by skimming include fats, waxes, soaps, mineral oils, petroleum products, etc. In addition, certain lightweight plastic particles often remain afloat and are removed by skimming devices.

4-4 CLARIFIERS

a. Types

Primary clarifiers are normally constructed as circular or rectangular tanks. Tanks are constructed of either reinforced concrete or steel. Exhibit 4-1 shows cross-sectional views of typical circular and rectangular clarifiers.

Circular clarifiers consist of a round tank with a concave type sloped bottom. The floor is shaped toward a hopper or sump in the center of the floor where the settled solids (sludge) are collected for removal. The settled sludge is collected by rotating scraper arms which rake the sludge from the floor to the hopper or sump. At the surface a skimming device is usually installed to remove floating matter from the water surface. Influent to the clarifier is usually baffled by a stilling well or similar device. Effluent normally leaves the clarifier over a series of small v-notch weirs spaced continuously around the perimeter of the tank at the water surface. A baffle is usually spaced a few inches inside the weirs to prevent floating and suspended matter from flowing over the weirs. Diameters of circular clarifiers usually range from 20 feet to 100 feet. Sidewall depths typically range from about 7 feet to 12 feet.

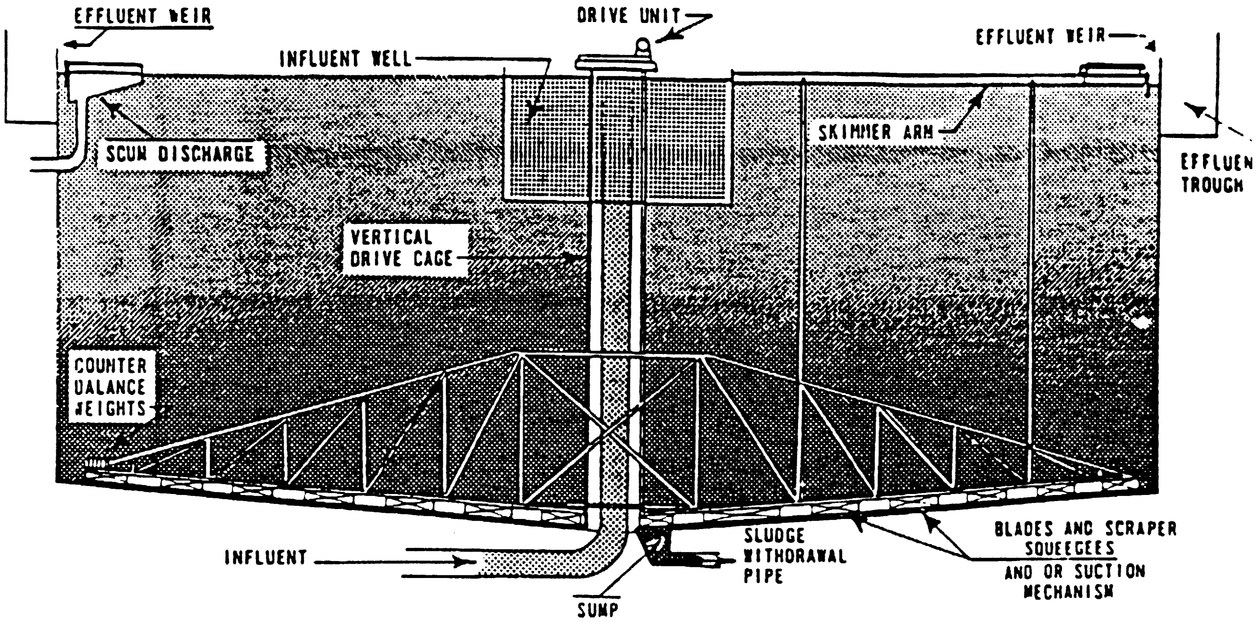
A circular clarifier can have various configurations with regard to the way in which influent enters the tank and effluent leaves the tank. Influent usually enters a clarifier either in the center (center-feed) of the tank or around the perimeter (rim-feed). Similarly, the effluent weirs are usually placed around the outer perimeter (rim-take off) or in a circle near the center (center-take off) of the tank. Exhibit 4-3 shows typical circular clarifier configurations.

Rectangular clarifiers are usually constructed so that the length of the tank is equal to or less than three times the width. The floor of the tank is typically sloped toward one end to a sump or hopper where the settled sludge is collected. Settled sludge is usually raked into the collection hopper by traveling flights or rakes driven by a chain drive. Influent and effluent baffles are normally provided. The clarified effluent usually leaves the tank over a series of v-notch weirs and troughs spaced at regular intervals. Lengths of rectangular clarifiers usually range from about 30 feet to as much as 300 feet. Widths vary from about 10 feet to 80 feet. Depths normally are in the range of 8 feet to 10 feet.

b. Sludge Removal

Removal of settled sludge from primary clarifiers, both circular and rectangular, can be achieved by numerous means. Regardless of the means, the objective is to simply remove the collected sludge from the hopper or sump and transport it to a digester for treatment. Removal of the settled sludge is usually achieved by one of the following means:

1. Gravity flow,
2. Sludge pumps, or
3. Air lifts.



CIRCULAR CLARIFIER

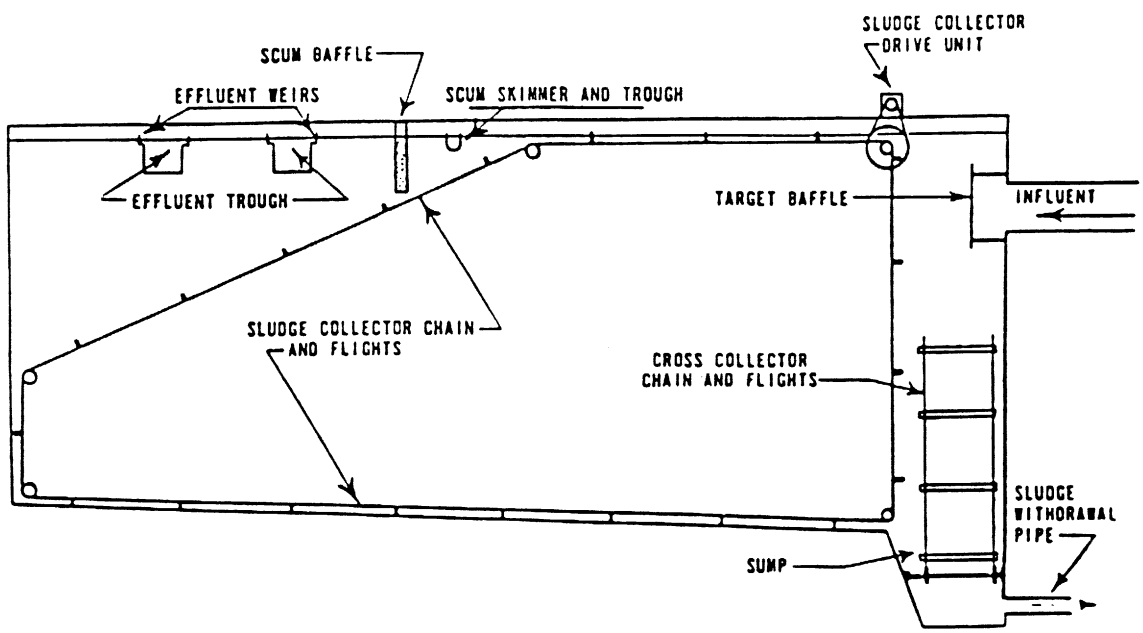


EXHIBIT 4-1

CROSS-SECTIONAL VIEWS OF

TYPICAL CIRCULAR & RECTANGULAR CLARIFIERS

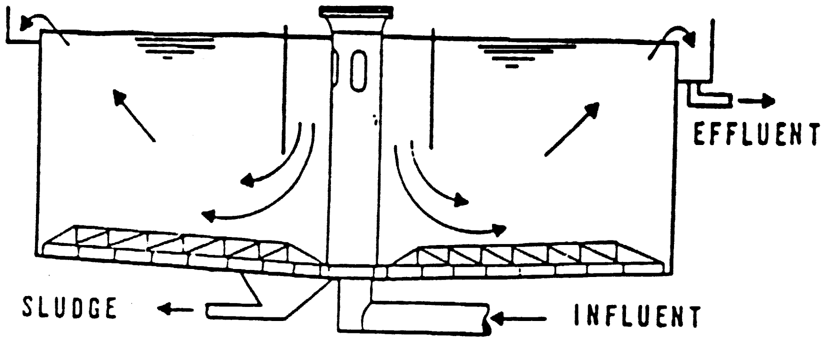
Source: Operation of Wastewater Treatment Plants Sacramento State College, Sacramento, California

PRIMARY CLARIFIER

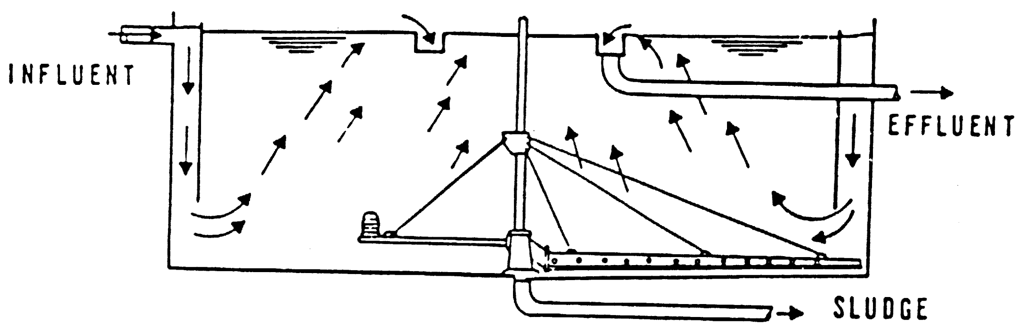
SLUDGE COLLECTION EQUIPMENT

EXHIBIT 4-2

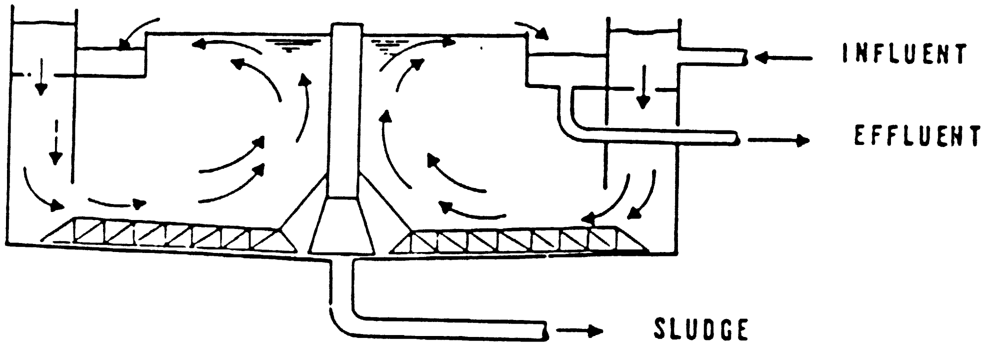
PRIMARY CLARIFIERS



CIRCULAR CENTER-FEED CLARIFIER



CIRCULAR RIM-FEED, CENTER TAKE-OFF CLARIFIER



CIRCULAR RIM-FEED, RIM TAKE-OFF CLARIFIER

EXHIBIT 4-3

TYPICAL CLARIFIER CONFIGURATIONS

Source: Clarification and Chemical Treatment EPA, March 1974

Settled sludge collected in a primary clarifier contains a significant amount of organic matter and, for this reason, needs to be subjected to further handling and treatment. The normal procedure is to remove the settled primary sludge and place it in a digester where it will undergo biological stabilization. After digestion, the sludge is typically routed to such facilities as drying beds and lagoons.

The frequency at which sludge should be removed from a primary clarifier depends on the concentration of the sludge. Settled primary sludge will generally have a suspended solids concentration in the range of 40,000 mg/l to 80,000 mg/l (4% to 8% solids). It is desirable to remove the primary sludge with as high a concentration as practical without interfering with the clarifier's operation. However, care should be taken to remove the sludge often enough to prevent it from becoming septic and thus causing gas bubbles and solids to rise to the surface. The objective in such practice is to keep the quantity of solids at a maximum and the quantity of water to a minimum to help digester performance.

c. Scum Removal

Floating material such as oils, grease, wax, soaps, etc. that collect on the surface of a primary clarifier must be removed. These floating materials are usually removed from the water surface by various skimming methods which include:

1. Rotating Mechanical Skimmer - A rotating arm simply sweeps or rakes the floating matter from the surface into a trough or pit.

2. Suction Air Lifts - A suction pipe is positioned at the water surface and vacuums the floating matter into the pipe.

3. Water Spray - A light surface spray pushes or directs the floating matter to a trough or pit.

4. Manual Skimming - Light blades, rakes, or nets are used to manually remove floating matter.

The floating matter which is removed are called skimmings and must be properly disposed of in such a way to prevent problems with other plant components. The most desirable method is to place the skimmings in a digester along with the primary sludge where biological activity can stabilize the material. Other methods sometimes used include landfill disposal and on-site burial.

d. Design Factors

There are certain factors which influence the operational efficiency of a primary clarifier that must be considered during design. These include:

1. Weir Overflow Rate (WOR) - This factor is defined as the volume of flow over one linear foot of weir per day. Mathematically, this value can be computed as follows:

$$WOR = \frac{\text{Flow (Gallons/Day)}}{\text{Total Length of Weirs (Ft.)}}$$

A primary clarifier should be designed to have a weir overflow rate in the range of 10,000 to 15,000 gallons per day per foot.

2. Surface Loading Rate (SLR) - The surface loading rate is a hydraulic loading factor expressed in terms of flow per surface area. This factor is also referred to as the "surface settling rate" or "surface overflow rate." Mathematically, the surface loading rate is computed as follows:

$$SLR = \frac{\text{Flow (Gallons/Day)}}{\text{Surface Area of Clarifier (Sq. Ft.)}}$$

   Typical values of surface loading rates for primary clarifiers are 600 to 1,000 gallons per day per square foot.

3. Detention Time (DT) - Detention time is the theoretical time wastewater is held in a clarifier based on the flow and volume of the tank. Mathematically, it is determined as follows:

$$DT = \frac{\text{Volume (Gallons)}}{\text{Flow (Gallons/Day)}} \times 24 \text{ Hours/Day}$$

   Most primary clarifiers are sized to have detention times in the range of 1½ to 2½ hours at average flow.

e. Performance Efficiency

The efficiency of a primary clarifier is generally determined in terms of the percentage of 5-day biochemical oxygen demand and suspended solids removed. The percent removal is based on the clarifier's influent and effluent values as follows:

$$\% \text{ Removal} = \frac{\text{Influent - Effluent}}{\text{Influent}} \times 100$$

Typical removals in a properly designed and operated primary clarifier are 25% to 40% of 5-day BOD and 50% to 65% of suspended solids.

4-5 COMMON OPERATIONAL PROBLEMS

The operation of a primary clarifier demands that regular attention be given to the equipment and facilities. A summary of the basic factors which must receive regular attention include:

1. Weirs and Baffles - All effluent weirs must be kept clean and level. Unlevel and/or unclean weirs will produce short-circuiting of flow and reduce efficiency. Baffles should be kept clean and adjusted as needed.
2. Scum Removal - Insufficient skimming will result in a carry-over of floating material in the effluent. The skimming mechanism must be strictly maintained in accordance with the manufacturer's recommendations and should be examined and adjusted as needed. Skimmings should be pumped to the plant's digester regularly.
3. Sludge Collection - The sludge collection mechanisms should be maintained strictly in accordance with the manufacturer's instructions. It should be periodically examined for wear and tear. The collection mechanism can be operated continuously or intermittently as needed.

Even with proper operational attention, there are certain problems which will normally occur with primary clarifiers.

Table 4-1 contains a list of common problems along with indicators and suggested corrective measures.

4-6 LABORATORY CONTROLS

As is the case with any major component of a wastewater treatment plant, it is necessary to utilize laboratory test results to establish, evaluate, and adjust the operation of a primary clarifier. Proper laboratory testing begins with representative samples collected at the proper location and at an adequate frequency. The actual laboratory analyses conducted on the samples should be confined to those which will reflect the function and performance of the primary clarifier.

Laboratory tests which are commonly conducted for the proper operation of primary clarifiers include:

1. Dissolved Oxygen - Dissolved oxygen should be determined to check for septicity of the clarifier effluent. Effluents that are completely void of oxygen are considered septic and cause unpleasant odors. If such conditions prevail, pre-aeration of the clarifier influent may be considered.
2. Settleable and Suspended Solids - Settleable and suspended solids are used to measure the effectiveness of the primary clarifier as well as to estimate the quantity of sludge to be removed from the clarifier.
3. Total and Volatile Solids - The results of the total and volatile solids, when combined with the suspended solids results, provide valuable information on the type, concentration, and quantity of solids handled by a clarifier. The quantity of volatile solids removed by a primary clarifier gives a measure of the loading on a digester in which the settled sludge is placed.
4. 5-Day Biochemical Oxygen Demand (BOD_5) - BOD_5 tests provide an excellent measure of the strength and quantity of the organic loading applied to the secondary treatment process which follows a primary clarifier.
5. pH - The pH value of the influent or effluent from a primary clarifier will serve as an indicator of whether any wastes of unusual characteristics, such as an industrial waste, have been placed in the system.

Table 4-2 lists typical laboratory results along with common sampling locations for primary clarifiers.

TABLE 4-1

COMMON OPERATING PROBLEMS

WITH

PRIMARY CLARIFIERS*

A. <u>Problem</u> FLOATING, GASEOUS, OR SEPTIC SLUDGE IN TANKS

<u>Indicators</u>

1. Floating material in tank deadspots or in scum troughs.
2. Odors of hydrogen sulfide origin.

<u>Monitoring, Analysis and/or Inspection</u>

1. Run total solids tests on raw sludge being pumped from primary sedimentation tanks with sample being taken at beginning and end of pumping cycle.
2. Dewater tanks and check sludge collector mechanism (flights, chains and scrapers) for wear and tear.
3. Observe conditions of tanks prior to chemical treatment of tank influent.

<u>Corrective Measures</u>

1. If total solids or raw sludge analyzed at end of pumping cycle is over 2%, increase duration of pumping cycle, preferably with a timer.
2. If sludge collector mechanism shows signs of wear during inspection, repair or replace.

3. Certain chemicals, such as alum, used in chemical treatment, cause floating sludge if this chemical is recirculated to the primary sedimentation tanks. Change operating procedures or chemicals used.

B. Problem — LOW SETTLEABLE SOLIDS REMOVAL EFFICIENCY

Indicators

1. Floating and gaseous sludges in tanks.
2. Percent settleable solids removal below 95%.

Monitoring, Analysis and/or Inspection

1. Run settleable solids test (Imhoff Cone) during times of day where there are appreciable changes in plant.
2. Check raw sludge removal pumping cycles and duration of pumping period.
3. Run total solids test on raw sludge removed from tanks both at beginning and end of pumping cycle.
4. Dismantle and/or inspect raw sludge pumps and sludge collection mechanism for wear and tear.
5. Check tank inlets with relation to the tank outlets. If baffles have been installed on the inlets, dewater the tanks and check their condition.
6. Calculate theoretical detention time, weir overflow rates, and surface loading rates and compare all data with design criteria.
7. Try a dye test to estimate flow-through time. Check for density stratification due to significant temperature or density difference top to bottom.

Corrective Measures

1. If efficiency or removal drops during peak or increased plant flows, the hydraulic capacity of tanks has probably been exceeded. Refer problem to consulting engineer.
2. Repair all worn raw sludge pump parts and sludge collector mechanism.
3. Damaged or missing inlet baffles could cause tank short circuiting whereby increased velocities from one end of the tank to the outlet end cause settleable matter to remain in suspension. Replace or repair baffles.

C. Problem — ERRATIC OPERATION OF SLUDGE COLLECTION MECHANISM

Indicators

1. Frequent replacement of broken shear pins on chain driven collector mechanisms.
2. Frequent torque switch activated alarms on concentrically driven clarifier equipment.
3. Visible slippage or “stuttering” of clarifier sludge collection mechanisms.

Monitoring Analysis, and/or Inspection

1. Check all drives for gear wear.
2. Dewater tank and check chains and sprockets for wear and see that chains have not come off sprockets.
3. Check to see that rags and debris have not entwined themselves around sludge collector mechanism.
4. Check dewatered tanks for excessive bottom deposits of sand, rocks and other inorganic material.
5. Sound bottom for excessive accumulation of sludge.

Corrective Measures

1. Repair all worn sludge collector equipment and drives.

2. If rags are a problem, make provisions for removal of all rags and debris as part of the pretreatment process.

3. If sand and rock deposits on the tank bottom are a problem, provide adequate screening and grit removal as a part of the pretreatment process.

4. If sludge accumulation is a problem, increase frequency of pumping raw sludge from tanks.

D. Problem — TANK CONTENTS TURN SEPTIC

Indicators

1. Tank contents are a dark color.

2. Hydrogen sulfide odors emitted from tanks.

Monitoring, Analysis and/or Inspection

1. Run total and dissolved sulfide tests on both tank influent and contents.

2. Run D.O. Test.

3. Check pH of tank influent.

4. Check quantity and total solids of all inflows into tank from other plant processes such as digesters supernatant, thickener, overflows, centrifuge concentrates, etc.

Corrective Measures

1. If tank influent contains high dissolved and total sulfides, influent is septic. Pre-chlorinate influent or correct problem at source.

2. If tank influent pH is below 6 or above 8, toxic waste possibly is being discharged into plant and must be corrected at the source.

3. If discharges from other plant processes contain excessive total solids and exceed 5% of the daily tank inflow, the sedimentation tank is being overloaded. If possible, reduce rate of process flows to sedimentation tanks or pretreat flows by aerating or chlorinating them. If possible divert or find other means of disposal for supernatant or centrates.

E. Problem — LOW SCUM (GREASE) REMOVAL

Indicators

1. Visible grease particles being discharged in plant effluent.

2. Excessive water in scum pits.

Monitoring, Analysis and/or Inspection

1. Run grease test (composite) on plant influent and effluent and calculate efficiency of grease removal equipment and compare with plant design criteria.

2. Observe if wooden flights making a return travel on tank surface carry grease particles adhered to them under scum troughs at the discharge end of the tanks.

3. Determine, with a pole, the depth of floating scum and water in scum pits.

4. Check capacity of scum pits.

Corrective Measures

1. If possible, lower return wooden flight to below water surface so grease particles do not adhere to them.

2. Install water sprays to direct grease particles on tank surface into scum troughs. Water spray should not break surface tension on water surface.

3. If scum removal is done manually and intermittently, continuous removal equipment should be installed.

4. Excessive water in scum pits should first be removed by pumping from bottom of pit to plant headworks and then the concentrated scum can be pumped to a digester or an incinerator.

5. Efficiency of scum removal in plants receiving a high grease loading can be increased by the addition of flotation or evacuator equipment.

6. Since grease particles normally in suspension tend to agglomerate into larger particles after being dosed with chlorine, chlorine contact tanks should be provided with grease removal equipment.

7. Pump scum pits down on a regular basis so as not to cause scum overflow back into the clarifier.

8. Clean and replace all worn wiper blades.

*Source: Procedural Manual for Evaluating the Performance of Wastewater Treatment Plants, EPA

TABLE 4-2

TYPICAL LABORATORY RESULTS FOR PRIMARY CLARIFIERS

TEST	SAMPLING LOCATION	RANGE OF TYPICAL TEST RESULTS
Dissolved Oxygen	Effluent	0 to 2 mg/l
Settleable Solids	Influent	5 to 15 ml/l
	Effluent	0.5 to 4 ml/l
Total Suspended Solids	Influent	100 to 350 mg/l
	Effluent	40 to 150 mg/l
	Sludge	4% to 8% solids
Total Solids	Influent	300 to 1,000 mg/l
	Effluent	250 to 800 mg/l
Volatile Suspended Solids	Influent	70 to 250 mg/l
	Effluent	30 to 120 mg/l
	Sludge	3% to 6% solids
5-Day Biochemical Oxygen Demand	Influent	100 to 400 mg/l
	Effluent	70 to 270 mg/l
pH	Influent	6.5 to 8.0
	Effluent	6.5 to 8.0

CHAPTER 5

BIOLOGICAL TREATMENT

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CHAPTER 5

BIOLOGICAL TREATMENT

5-1 BASIC CONCEPTS AND TERMINOLOGY

Biological treatment methods are those in which the removal of pollutants is brought about by the biological activity of microorganisms. Pollutants are those substances which contaminate or "pollute" the environment. In domestic wastewater, the primary pollutant is organic matter. The basic objective of biological wastewater treatment methods is to reduce the organic content to a level which can be discharged to the environment without harmful effects. Generally, at least 85% of the organic matter in typical domestic wastewater can be removed by biological treatment. With certain biological methods, removals in excess of 95% can be routinely achieved.

Bacteria are the principle microorganisms which are responsible for providing the "treatment" in biological systems. The natural life processes of the bacteria are such that, much like humans, they need food, water, and oxygen in order to survive. Organic matter serves as a food source for bacteria. It, along with water and the bacteria themselves, are naturally and abundantly present in normal domestic wastewater. The only ingredient not present in adequate supply in wastewater is oxygen. This missing ingredient is supplied at the biological treatment facility, thereby making available to the bacteria all the substances necessary for their life cycle. Thus, the role of the treatment facility is simply to provide an environment which will allow the natural biological processes of the bacteria to take place.

With all the necessities available in adequate supply, bacteria consume the organic matter and convert it into gases such as carbon dioxide (CO_2) and ammonia (NH_3) and into biological cell tissue. This biological process of converting the organic matter into gases and cell tissue is often referred to as "oxidation" or "stabilization" of the organic matter. The conversion is a two-part process. The process called "respiration" results in the production of gases and the process of "synthesis" yields the cell tissue. Approximately 70% of the organic matter (expressed as BOD) is typically consumed by the bacteria for respiration and about 30% is consumed for synthesis. Removal of the gases is achieved by escapement to the atmosphere. The cell tissue, because it has sufficient weight, can be removed by simple gravitational settling in a clarifier. Cell tissue forms what is called "sludge" in an activated sludge process and "humus" or "sloughings" in a trickling filter process.

In discussing biological treatment systems, there are numerous terms which are commonly used and with which an operator of such a system should be familiar. These include the following:

1. Aerobic Processes - Biological treatment processes that occur in the presence of free oxygen.
2. Anaerobic Processes - Biological treatment processes that occur in the absence of free oxygen.
3. Facultative Processes - Biological treatment processes that occur with or without the presence of free oxygen; the organisms are indifferent to the presence of free oxygen.
4. 5-Day Biochemical Oxygen Demand (BOD_5) - The amount of dissolved oxygen required by microorganisms (primarily bacteria) while stabilizing organic matter under aerobic conditions during a 5-day period.

5. Stabilization - The biological process by which organic matter is converted to cell tissue and various gaseous end products.

6. Nitrification - The biological process whereby ammonia nitrogen (NH_3/NH_4^+) is converted to nitrate nitrogen (NO_3-).

7. Dentrification - The biological process whereby nitrate nitrogen (NO_3^-) is converted to nitrogen gas (N_2).

8. Suspended Growth Processes - Biological treatment processes in which the microorganisms responsible for stabilizing organic matter are maintained in suspension within the liquid; the activated sludge process is an example.

9. Attached Growth Processes - Biological treatment processes in which the microorganisms responsible for stabilizing organic matter are attached to some inert medium; a trickling filter is an example.

There are numerous biological processes utilized in the treatment of wastewater. The most common are identified in Table 5-1. Detailed discussions of activated sludge, trickling filter, and lagoon systems are presented hereinafter in this chapter. Anaerobic and aerobic digestion are discussed in Chapter 8. Two-stage biological nitrification and 3-sludge systems are addressed in Chapter 6.

TABLE 5-1

MAJOR BIOLOGICAL WASTEWATER TREATMENT PROCESSES

TYPE	COMMON NAME	USE
I. Aerobic Processes		
A. Suspended Growth	Activated Sludge	
	Conventional	BOD Removal
	Complete-Mix	BOD Removal
	Contact Stabilization	BOD Removal
	Extended Aeration	BOD Removal/Nitrification
	Oxidation Ditch	BOD Removal/Nitrification
	Two-Stage Bio Nitrification	BOD Removal/Nitrification
	Sequencing Batch Reactors	BOD Removal/Nitrification
	Aerobic Digestion	Sludge Stabilization
B. Attached Growth	Trickling Filter	BOD Removal
	Rotating Biological Contactors	BOD Removal/Nitrification
II. Anaerobic Processes	Anaerobic Digestion	Sludge Stabilization
	Anaerobic Lagoon	BOD Removal
III. Facultative Processes	Conventional Lagoon	BOD Removal
	Aerated Lagoon	BOD Removal
IV. Combined Aerobic & Anaerobic	3-Sludge System	BOD Removal/Nitrification & Denitrification

5-2 MICROORGANISMS IN BIOLOGICAL TREATMENT

The basic role of microorganisms in the biological treatment of wastewater is to convert organic matter into various gases and cell tissue. Because the cell tissue is slightly heavier than water, it can thence be removed from the wastewater by gravity settling. Unless the cell tissue produced by the microorganisms is removed, complete treatment (removal of organics) will not be achieved because the cell tissue itself is organic. Without removal of cell tissue, the only "treatment" that would be achieved is the conversion of a portion of the organic matter to the various gaseous end-products. It is microorganisms which actually provide "biological treatment" by converting the pollutant (organics) into forms which can be easily removed; i.e. gases which escape to the atmosphere and cell tissue which will be heavy enough to settle.

There are a variety of microorganisms which are normally associated with biological treatment systems, although "bacteria" are the principal workers in actually stabilizing organic matter. Microorganisms can be classified in a number of ways, beginning with the basic group of living organisms to which they belong. For years it was customary to group all living organisms into the two basic kingdoms of plants and animals. However, in recent years the practice has been to group microorganisms into three (3) kingdoms; plant, animal, and protista. Plants and animals are typically characterized as multi-cell organisms whereas protists can be either single-cell or multi-cell. Some of the microorganisms typically associated with biological treatment of wastewater are classified into the three (3) kingdoms in Table 5-2.

TABLE 5-2

CLASSIFICATION OF COMMON WASTEWATER MICROORGANISMS BY KINGDOM

KINGDOM	REPRESENTATIVE MEMBERS
Animal	Rotifers Crustaceans
Plant	Mosses Ferns Seed Plants
Protista	Algae Protozoa Fungi Slime Molds Bacteria

Another way in which microorganisms are classified is in accordance with their sources of energy and carbon. It is necessary that organisms have a source of energy and carbon for the synthesis of new cell tissue. The two most common sources of carbon are carbon dioxide (CO_2) and organic matter. Organisms which obtain their carbon from carbon dioxide (CO_2) are called “autotrophic”, whereas those that utilize organic matter are called “heterotrophic”. Autotrophic organisms obtain their energy from sunlight through the process of photosynthesis or from an inorganic oxidation-reduction reaction. Energy for heterotrophic organisms is supplied by the oxidation of organic matter. The classification of microorganisms by sources of energy and carbon is summarized in Table 5-3.

TABLE 5-3

CLASSIFICATION OF MICROORGANISMS BY ENERGY/CARBON SOURCES

CLASSIFICATION	ENERGY SOURCE	CARBON SOURCES
Autotrophic		
Photosynthetic	Sunlight	Carbon Dioxide (CO_2)
Chemosynthetic	Inorganic Oxidation - Reduction Reaction	Carbon Dioxide (CO_2)
Heterotrophic	Organic Oxidation - Reduction Reaction	Organic Matter

Another way of classifying organisms, which is important in biological treatment, is according to their ability to use oxygen (O_2). Organisms which can exist only when oxygen is available are called “aerobic”; whereas those which exist only in the absence of oxygen are called “anaerobic”. Organisms which have the ability to exist with or without oxygen are called “facultative”.

Certain microorganisms are of more significance in biological treatment than others. Bacteria are the most important because of their primary role in stabilizing organic matter. However, other microorganisms also have significant roles. Those microorganisms regarded as being important to biological treatment because of their roles therein are generally described as follows:

1. Bacteria - Bacteria are the principal workers in biological treatment processes because they reduce the amount of organic matter, which is the major pollutant in domestic wastewater. These microorganisms achieve reduction of organics by converting it to new cell tissue and gases. Bacteria are single-cell protists which are naturally present whenever moisture and a food source are available. They can be either autotrophic or heterotrophic. Heterotrophic bacteria are the most prominent microorganisms in biological treatment of wastewater because of their need for organic matter as a source of carbon. Bacteria can be aerobic, anaerobic, or facultative.
2. Algae - Algae exist as both single-cell and multi-cell protists. They are autotrophic and their major role is the production of oxygen in environments such as lagoon systems. Said oxygen production is achieved in the presence of sunlight through the process of photosynthesis. The photosynthetic process is one by which algal cells containing a green pigment known as chlorophyll transform radiant

energy from sunlight into chemical energy. The process produces oxygen (O_2) from water molecules (H_2O) and converts carbon dioxide (CO_2) to new algae cells. At night in the absence of sunlight, instead of producing oxygen, algae consume it through the process of respiration. Algae have a significant influence on the pH of lagoon contents because of their use of carbon dioxide. During the daylight hours, algae consume carbon dioxide for photosynthesis which results in the pH being raised. At night during respiration, carbon dioxide is produced which results in the pH being lowered. The pH in a lagoon will increase as the amount of algae therein increases because the consumption of carbon dioxide increases.

3. Protozoa - Most protozoa are single-cell, aerobic, and heterotrophic protists. They are usually larger than bacteria and serve in the role of effluent polishers by consuming bacteria and undissolved organic matter.

4. Rotifers - Rotifers are aerobic, heterotrophic, multi-cell animals. Its name "rotifer" is derived from the fact that it has two sets of rotating cilia on its head which are used in capturing food and for movement. Rotifers tend to live only in relatively pollution-free environments; and their presence in an effluent usually indicates a highly efficient aerobic process. Thus, their role is basically one of being an indicator of water quality. If they are present in a receiving stream, it is usually an indication of efficient treatment and good water quality.

5. Crustaceans - Crustaceans are aerobic, heterotrophic, multi-cell animals. They have a hard shell body. They are a common food source for fish and are normally found in natural waters. Their presence within a biological treatment process is rare. However, their presence in a receiving stream indicates that conditions are relatively unpolluted and that any effluent being discharged thereto is low in organic content and high in oxygen content. Thus, their role, like rotifers, is one of serving as an indicator of a pollution-free environment.

6. Fungi - Fungi are multi-cell heterotrophic protists whose major role is the treatment of certain industrial wastewaters. Most fungi are strictly aerobic. They have the ability to survive under conditions of low pH and low nitrogen content, which contributes to their prominence in the biological treatment of industrial wastes.

7. Viruses - A virus is the smallest biological structure capable of reproducing itself. An electron microscope is needed to see viruses. They are known to infect man with various diseases. Their significance in biological treatment is generally confined to the need for their destruction via a disinfection process.

The existence or non-existence of the aforementioned microorganisms within a biological wastewater treatment process or in waters which receive a treated effluent is important. Regular microscopic examination of effluents, receiving waters, and wastestreams within a process is strongly encouraged. Compilation of data from such examinations can reveal much about the quality of effluent being produced, about the environmental quality of the receiving stream, and about existing or potential operational problems within a process. A microscope and routine examination of process and receiving waters should be an integral part of operational procedures for any biological wastewater treatment process.

5-3 CONVENTIONAL (UN-AERATED) LAGOONS

a. Process Description

The term "lagoon" usually refers to an un-aerated relatively shallow body of water contained in an earthen basin of controlled shape designed for the purpose of treating wastewater. The terms "oxidation pond" and "stabilization pond" are also sometimes used to refer to a conventional un-aerated lagoon. Conventional lagoons are constructed both as single-cell and multi-cell facilities. Multi-cell lagoons usually contain two or three cells. The typical characteristics of conventional lagoons in Mississippi are shown in Table 5-4.

TABLE 5-4
TYPICAL CHARACTERISTICS
OF
CONVENTIONAL (UN-AERATED) LAGOONS

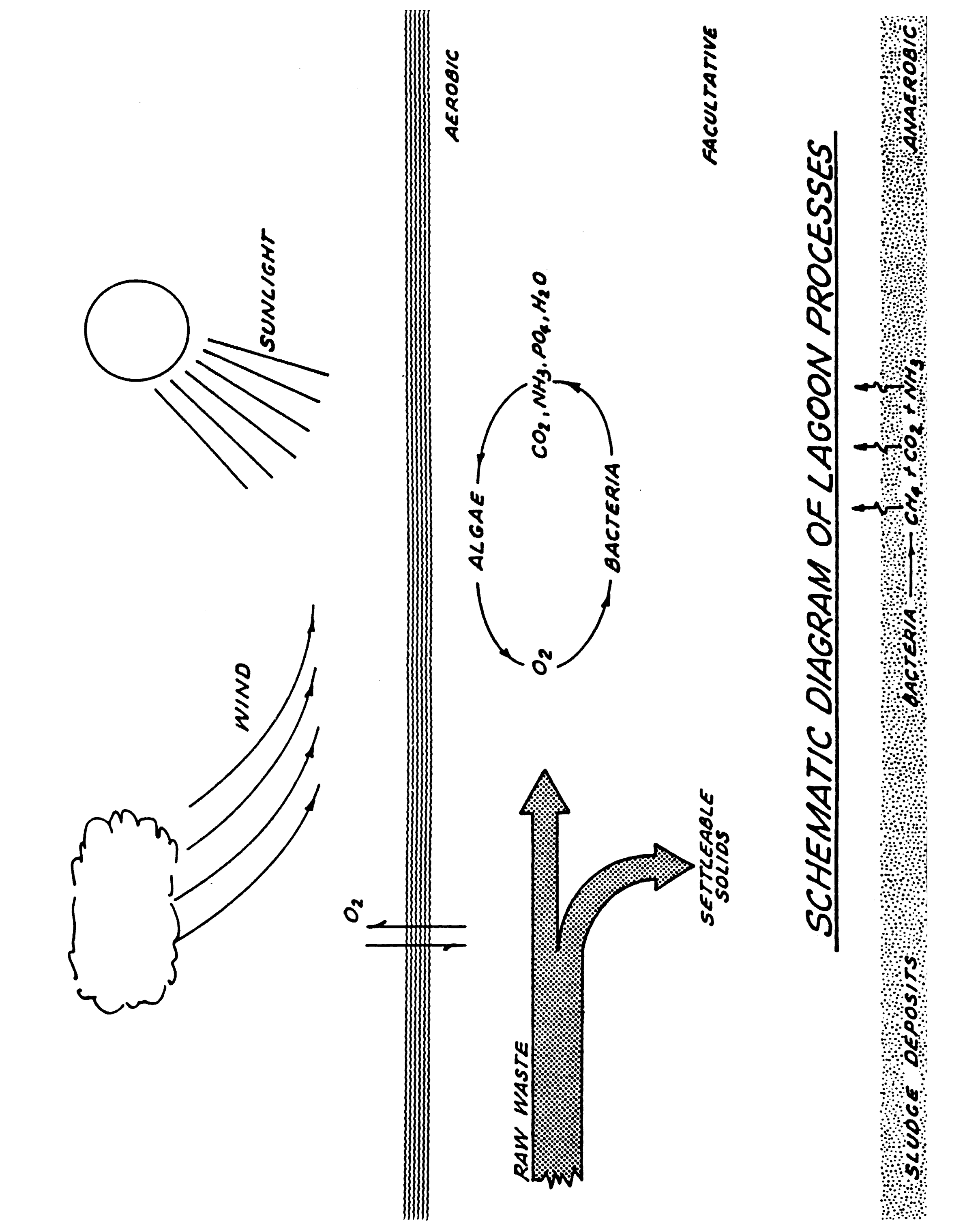
PARAMETER	TYPICAL VALUE/CONDITION
Primary Oxygen Source	Algal Photosynthesis
BOD5 Loading	30 to 50 Lbs/Day/Acre
Water Depth	4 to 6 Feet
Detention Time	40 or more Days
BOD5 Removal	75 to 85%
TSS Removal	50 to 60%
Levee Freeboard	Minimum of 2 Feet
Levee Width @ Top	Minimum of 10 Feet
Levee Side Slopes	Maximum of 3H:1V
Disinfection of Effluent	May Be Required
Separate Effluent Settling Basin	Not Required

The use of lagoons is a very popular method of wastewater treatment, especially in smaller communities, because of their relatively low construction and operation/maintenance costs. However, there is less process "control" available with a lagoon system. This generally means that the quality of effluents produced by lagoons is not as high as that produced by activated sludge or trickling filters.

The processes which occur in a conventional lagoon are illustrated in Exhibit 5-1. As can be seen from the illustration, two (2) processes actually occur. One of these is the physical process of settling. Unlike activated sludge or trickling filter systems which have primary and/or secondary clarifiers, lagoons typically do not have separate settling facilities. The settleable matter in the raw waste plus any settleable matter produced by biological activity within the lagoon settle out in the lagoon itself. The settled matter collects on the lagoon bottom and forms a sludge layer which remains in place for the life of the lagoon.

The second process which occurs is the biological stabilization of organic matter; which is the same basic process that takes place in activated sludge or trickling filter systems. The major microorganisms involved in this biological process are bacteria and algae. Stabilization is primarily accomplished by aerobic bacteria which consume the organic matter in the raw wastewater and convert it to carbon dioxide (CO_2) and various other end-products. Algae, through the process of photosynthesis, produce oxygen (O_2) which the bacteria also need to survive and thereby stabilize the organic matter. The bacteria in turn produce carbon dioxide (CO_2) and other end-products such as ammonia (NH_3) and phosphate (PO_4) which the algae consume to support their life cycles. Thus, a dependency develops between the algae and bacteria.

EXHIBIT 5-1



The process of algal photosynthesis is a phenomenon in which chlorophyll converts sunlight into energy for growth. The bacterial oxidation (stabilization) of organic matter yields carbon dioxide (CO_2) and nutrients such as ammonia (NH_3) and phosphate (PO_4) which, in turn, are consumed by the algae. In the presence of sunlight, photosynthesis provides the necessary energy for the algae to convert the carbon dioxide (CO_2) and nutrients (NH_3 and PO_4) into additional algae cells and to produce oxygen (O_2). The algae cell material is organic and thus it can be expected that the effluent from a lagoon will contain a significant amount of organic matter due to the presence of the algae. However, the organic matter represented by the algae is significantly different from that in the raw wastewater. The organics contained in raw wastewater are highly putrescible and hazardous to public health, whereas those in algae cells are stable and have no pathogenic significance.

During daylight hours when the sunlight is present, the algae produce a large amount of oxygen (O_2) as a result of photosynthetic activity. While they are producing oxygen (O_2) they are also consuming carbon dioxide (CO_2). At night in the absence of sunlight, photosynthesis ceases; but there is typically an excess of oxygen (O_2) available for the bacteria from the day's photosynthetic activity. Also, during the absence of sunlight and photosynthetic activity, the algae actually reverse their role and consume oxygen (O_2) through the process of respiration. In any event, the net result of a lagoon process is biological activity which results in the organic and nitrogenous matter in raw wastewater being converted into algae cells.

A typical conventional lagoon is generally classified as a facultative process. As can be seen from Exhibit 5-1, the bottom sludge layer is anaerobic and the upper zone is aerobic. Anaerobic decomposition of settled solids occurs in the sludge layer and results in the production of gases such as methane (CH_4), carbon dioxide (CO_2) and ammonia (NH_3). The upper reaches of the lagoon contents are aerobic. The combination of both aerobic and anaerobic conditions makes it possible for facultative bacteria to survive and implement the stabilization processes.

Most conventional lagoons are constructed of regular shapes. Rectangular shapes are the most common with length to width ratios less than 4. Circular and irregular shapes have also been used. The major components in a typical lagoon in Mississippi include the following:

1. Inlet Pipe - The raw wastewater is usually discharged out in the center portion of a lagoon away from the immediate proximity of any sides or corners. The discharge is usually near the bottom. A concrete splash pad is usually placed under the end of the discharge pipe. Cast iron and ductile iron are the most commonly used materials for inlet pipes.

2. Outlet Structure - The effluent from a lagoon usually is discharged through an outlet structure located on one side of the lagoon. The outlet structure should include an adjustable weir or a series of valved outlets which will allow the water level in the lagoon to be adjusted. Also, some type of effluent skimming device should be provided.

3. Lagoon Levees - A lagoon should be diked with a continuous levee to prevent surface run-off from entering the lagoon and to protect against floodwaters. To prevent erosion, which is a common problem in many lagoons, the levees are often protected with a concrete apron or rip rap.

Exhibit 5-2 shows a conventional lagoon in use in a Mississippi community.

EXHIBIT 5-2

CONVENTIONAL FACULTATIVE LAGOON

b. <u>Process Controls & Performance Indicators</u>

A conventional lagoon is somewhat limited in operational controls. It has been said that "mother nature" is the chief operator of a lagoon in reference to the dependency on sunlight and algal photosynthesis. This is not to say, however, that the operator of a lagoon is without any controls or parameters to evaluate performance.

While "control" devices are somewhat limited, there are several parameters which can be used to assess a lagoon's performance and assist an operator in responding to certain situations. These include the following:

1. BOD Loading - The BOD loading is defined as the organic load, expressed in terms of BOD_5, applied per unit of lagoon water surface area. Mathematically, it is usually expressed in units of pounds of BOD_5 per day per acre (Lbs/Day/Acre) and can be computed as follows:

$$\text{BOD Loading Rate} = \frac{\text{BOD}_5 \text{ Applied (Lbs/Day)}}{\text{Water Surface Area (Acres)}}$$

Typical values will normally be in the range of 30 to 50 Lbs/Day/Acre for most conventional facultative lagoons. The BOD loading is also referred to as "organic loading" or "surface loading". A lagoon which has an excessive BOD loading will usually experience odors or other operational problems.

2. Water Depth - Most conventional lagoons will have water depths in the range of 4 to 6 feet and will have an outlet structure which can be adjusted to vary the water depth within this range. It is often advantageous to vary the water depth seasonally. A higher water depth can be maintained during the summer months and a lower depth can be maintained during winter months to enhance photosynthetic action. During periods of heavier rainfall, if a sewer system experiences significant infiltration/inflow that will ultimately be discharged to the lagoon, it may be advisable to operate the lagoon at maximum depth in order to provide ample detention time. Also, raising and lowering water depth will assist in controlling weed growth and burrowing animals along a lagoon's dikes.

3. Detention Time - The desirable detention time in a typical conventional lagoon is usually greater than 40 days based on average daily design flow. It can be computed as follows:

$$\text{Detention Time (Days)} = \frac{\text{Volume of Lagoon (MG)}}{\text{Flow to Lagoon (MGD)}}$$

   The detention time can be adjusted by varying the water depth in the lagoon. Lowering the depth will decrease the detention; whereas raising it will result in a greater detention time.

4. Wind Action - The wind creates surface mixing in lagoons. This mixing can remove oxygen from the water when the lagoon is supersaturated with oxygen or it can add oxygen when the content is less than supersaturated. Observation of prevailing winds can often be correlated to dissolved oxygen content in a lagoon which is important in achieving sufficient BOD_5 removal. It is for these and other reasons that dikes and levees should be kept free of trees, bushes, etc. which could block the wind.

5. Temperature - Temperature is important to a lagoon's performance for two reasons. First, the water in a lagoon will hold more oxygen (O_2) per unit volume at a cold temperature than it will at a warmer temperature. Secondly, biological activity decreases with a reduction in temperature. For example, a 10-degree drop in temperature can reduce bacterial activity by fifty percent (50%).

   The most desirable conditions are when it is warm with ample sunlight and a moderate breeze. Such conditions produce the greatest bacterial activity and hence the highest BOD_5 removal. During the winter months when the weather is colder and the daylight hours are shorter, bacterial and algal activity is reduced.

6. Sunlight - Sunlight is vital to the efficient operation of a lagoon. Without it, algal photosynthesis would not take place and the oxygen (O_2) content would drop. The amount of available sunlight is a significant factor in determining how well a lagoon operates and the area and depth needed for proper operation. The depth of sunlight penetration determines the extent to which the lagoon contents participate in oxygen (O_2) production. The thickness or density of the algae in a lagoon affects the sunlight penetration. As a general rule, with a good algae growth, the sunlight penetration and hence oxygen (O_2) production will be limited to the upper 2 to 3 feet.

7. Nutrients - In addition to organic matter and oxygen (O_2), the bacteria in a lagoon need a sufficient supply of nutrients to grow and multiply. Nitrogen in the form of ammonia (NH_3) and phosphorus in the form of phosphate (PO_4) are the main nutrients needed. Domestic wastewater normally will have sufficient quantities of each, but occasional monitoring of the influent and lagoon contents is considered good practice.

8. pH - The pH of a lagoon indicates whether its contents are acidic or alkaline. An alkaline environment produces the best results. Regular monitoring of pH can help detect the presence of toxic materials or other substances which might upset a lagoon. The color of the water in a lagoon is usually related to pH and can be used to forecast potential problems. Generally, the greener the color, the higher the pH will be. A yellowish-green tint usually indicates a falling pH.

   The pH normally will vary throughout the day depending on the algal activity. Because algae are most active during the daylight hours (photosynthesis), the carbon dioxide (CO_2) level is at its lowest, thereby increasing the pH. Conversely, just the opposite is true during the night when carbon dioxide

(CO_2) is being produced by algal respiration. Hence, the lowest pH normally can be expected during the early morning and the highest during the late afternoon.

9. Dissolved Oxygen - It is vital that sufficient dissolved oxygen be available for the bacteria in a lagoon. Otherwise, the biological treatment processes will not take place and the lagoon will not accomplish its intended purpose. During the warm months of the year when algal activity is at its highest, it is not uncommon for the dissolved oxygen content to reach the saturation point. It is good practice to monitor dissolved oxygen in a lagoon to establish what is normal for that lagoon and thereby be able to notice any drastic changes or gradual trends which may be indicative of potential problems.

10. Flow - Flow is a very important parameter in monitoring the performance of a lagoon. In most instances, effluent flow from a lagoon is measured at the outlet structure by means of a weir. Regular flow monitoring is needed for several reasons which include:

    a. It is required for NPDES permit compliance.

    b. Accurate flow data is needed to calculate BOD loadings.

    c. Records compiled from regular flow monitoring will serve as a basis for evaluating the amount of infiltration/inflow which occurs. Over a reasonable period of time, an operator can estimate the amount of infiltration/inflow which is contributed by certain amounts of rainfall.

    d. Effluent quality and performance can be related to flow if accurate flow records are maintained. This will allow the operator to evaluate the effects of high and low flows on effluent quality.

The use of the above-cited parameters as meaningful tools in operating a lagoon is dependent on the individual operator. In essence, all of the parameters, except for the BOD loading and water depth, serve only as "indicators" rather than actual "controls". It is the judgement and action of the operator in responding to these indicators that can make a difference in the performance of a lagoon.

c. <u>Methods of Upgrading</u>

Effluent limits for such parameters as biochemical oxygen demand, ammonia nitrogen, and suspended solids have steadily become more stringent in recent years. This increased stringency has led to the need for many conventional lagoon systems to be upgraded in order to enhance treatment capability and thereby produce effluents of higher quality. Upgrading methods utilized in Mississippi include the addition of components within a lagoon, modification of effluent discharge practices, and addition of separate physical or biological treatment components. The more common methods utilized to upgrade an existing lagoon system and/or to include with a new lagoon system to meet more stringent effluent requirements can be described as follows:

1. Baffles - The addition of flow baffling to a lagoon cell can enhance performance by minimizing hydraulic short-circuiting and thereby maximizing detention time. Installation of baffles in a lagoon cell has the effect of converting the cell into a multi-cell facility in which organic loading is continuously being decreased as the flow travels in a well defined pattern from inlet to outlet. This decrease in loading through the lagoon tends to reduce algal growth because fewer nutrients are available as the flow makes its way through the lagoon. In addition, there is some additional organic reduction achieved because of the bacterial growths which become attached to the baffles.

    Probably the most common type of baffling used in lagoons are plastic curtains which have flotation devices at the water surface and anchoring at the bottom.

2. Hydrograph-Controlled Release (HCR) - In hydrograph-controlled release systems, lagoon effluent is discharged only when the flow in the receiving stream is sufficiently high to assimilate the wasteload. This method of intermittent discharge requires that the lagoon system have sufficient storage to retain all flow until such time that the flow in the receiving stream is high enough to receive effluent

discharge. Typically, storage of least 90 to 120 days is required. Streamflow and hydrologic data must be compiled to develop sufficient hydrographic information on a stream before this system can be used. Where a HCR system can be used, it offers two (2) advantages. First, because effluent discharge is normally made at high flows in the receiving stream, the assimilative capacity of the stream will be more efficiently utilized. Secondly, during long periods of no discharge, the receiving stream will assume a higher natural water quality than normally exists with a continuous lagoon discharge.

3. Sand Filtration - Routing a lagoon effluent through sand filters is very effective in improving suspended solids removal. Said process is basically a physical process whose major function is algae removal. Bacterial action does occur within the sand media which can result in additional reduction of biochemical oxygen demand and ammonia nitrogen from that achieved by a lagoon alone. However, the bacterial activity within the sand media is not controllable in the same sense as that associated with conventional biological processes (activated sludge, trickling filters, etc.); and thus, the major benefit derived from sand filters is the removal of suspended matter, particularly algae.

   Sand filters are usually constructed utilizing 24 to 36 inches of sand over a gravel base that contains a perforated pipe underdrain. Filter sand typically has an effective size in the range of 0.20 to 0.30 millimeters with less than one percent (1%) being 0.10 millimeter.

   The application of lagoon effluent onto sand filters may be continuous or intermittent with hydraulic loadings ranging from 5.0 to 10.0 gallons per day per square foot. Maintenance is required whereby a filter will need to be removed from service, allowed to dry, and thence scarified or raked to break up algal/solids build-up on the surface. Such maintenance typically should be achieved whenever ponding occurs, when treatment efficiency begins to drop, or at least every three (3) months. After a few years of service, it may be necessary to remove and replace the top few inches of sand. Exhibit 5-3 shows sand filters in operation.

4. Overland Flow Systems - In an overland flow system, lagoon effluent is applied to land area by a network of sprinklers. The area is generally a graded and sloped field covered with grass or other vegetation. Soil types in overland flow systems are normally not very pervious which results in little percolation. As the lagoon effluent flows over the field, it is filtered and stabilized when it passes over the soil surface and through the vegetative cover. The fields are usually graded at uniform slopes of 2% to 8% (2 feet/100 feet to 8 feet/100 feet). The run-off which remains after evaporation and vegetative consumption is typically collected via a drainage system and thence disinfected prior to final discharge. Exhibit 5-4 shows overland flow systems in operation.

5. Spray Irrigation - Spray irrigation systems are designed and operated in much the same way as overland flow systems. The primary difference is that spray irrigation systems usually do not have a discharge into a stream. Instead, they are provided with sufficient land application area to prevent discharge through percolation and evaporation. Usually, multiple application fields are provided to assure adequate field rotation and prevent run-off. Hay or other agricultural crops and golf courses are often ideal applications for spray irrigation.

6. Constructed Wetlands - Wetlands have been described as being a transition zone between a terrestrial and an aquatic environment. They consist of areas that are periodically inundated by surface or ground water at a frequency and duration sufficient to maintain saturated conditions and promote the growth of water-tolerant plants such as cattails, bulrushes, hyacinths, duck weed, and reeds. Effluent from a lagoon system can be further treated by a wetlands environment through physical sedimentation, filtration, and bacterial activity.

   Even though naturally-existing wetlands are sometimes utilized, it is far more common to utilize man-made (constructed) wetlands because of hydraulic controls which can be designed into the systems. Constructed wetlands generally are shallow bodies of slow-moving water (lagoon effluent) in which dense growths of specified vegetation are maintained. They are usually constructed as long narrow trenches or channels as either free water surface systems or as subsurface flow systems with water flowing laterally through sand or gravel. The aquatic plants in a wetlands system provide very little actual treatment of the lagoon effluent. Instead, their primary function is to support various components of the aquatic environment that contribute to the treatment processes. Roots and stems

EXHIBIT 5-3

SAND FILTERS FOLLOWING LAGOONS

EXHIBIT 5-4

OVERLAND FLOW SPRAY FIELDS

below the water surface provide surfaces on which bacteria grow and stabilize organic matter in the lagoon effluent. In addition to providing surfaces for bacterial growth, roots and stems in the water serve as a media for filtration and adsorption of solids. Stems and leaves at or above the water surface reduce the intensity of sunlight, thereby reducing and/or preventing the growth of algae. They also reduce the transfer of gases between the atmosphere and water and assist in the transfer of gases to and from submerged parts of plants. Organic reduction is also achieved in the bottom layers of wetlands which contain humus deposits. Exhibit 5-5 shows constructed wetlands in operation.

d. Laboratory Controls

Laboratory analyses of collected samples are essential for the proper evaluation and control of the performance of any wastewater treatment facility. Laboratory tests are used to determine process efficiency; evaluate performance; analyze waste strength and characteristics; and trace, identify, and evaluate operational problems. The first step in compiling good laboratory test results is the collection of good samples. It is important that a sample be as representative as possible of the conditions which it is intended to reflect. Sampling locations in a lagoon are typically confined to the influent and effluent and occasionally to the lagoon itself. Two (2) types of samples can be collected. One is a "grab" sample which consist of a single portion taken at a given time. Grab Samples are usually used to measure such parameters as temperature, pH, and dissolved oxygen. The other type of sample is a "composite" sample and consists of portions taken at known times and then combined into a single sample. Composite samples are preferred for such analyses of BOD_5 and total suspended solids.

The most common laboratory analyses and field tests needed for the proper operation and control of a lagoon include the following:

1. 5-Day Biochemical Oxygen Demand (BOD_5) - The BOD_5 analysis is typically conducted on the influent and effluent and the results used to determine removal efficiency. Also, the influent results are used to determine the BOD loading on a lagoon.
2. Total Suspended Solids (TSS) - The TSS analysis is typically conducted on the influent and effluent and the results used to determine removal efficiently.
3. Dissolved Oxygen (DO) - The dissolved oxygen content of a lagoon and its effluent should be monitored and correlated with BOD removal results.
4. pH - The pH of the influent, effluent, and lagoon contents should be monitored and correlated with BOD removal results.
5. Temperature - The temperature of the atmosphere and the lagoon contents should be monitored and correlated with BOD removal results.
6. Microscopic Examination - Microscopic examination of a lagoon contents and the receiving stream are often utilized to evaluate the various kinds of microorganisms which are present. Such examination is frequently helpful in identifying the type(s) of algae present in a lagoon.
7. Nutrient Content - When the need arises, it sometimes is necessary to evaluate the nutrient content in a lagoon. This usually involves conducting analyses for ammonia, nitrates, and phosphates.

e. Common Operational Problems

Inherent with any wastewater treatment process are various operating problems which can produce undesirable situations ranging from nuisance conditions to violation of Federal and State pollution control requirements. It is inevitable that a lagoon system will experience operational problems, and it is this inevitability which justifies the need for competent and qualified operating personnel.

EXHIBIT 5-5

CONSTRUCTED WETLANDS FOLLOWING LAGOONS

Before an operational problem can be solved, it must first be identified. Once it has been identified, further investigation of a problem can range from a simple visual observation to detailed and precise laboratory analyses.

Some of the common operational problems, along with their causes and cures, that are typically experienced with conventional lagoons are presented in Table 5-6.

5-4 AERATED LAGOONS

a. Process Description

An aerated lagoon is a relatively deep body of water contained in an earthen basin of controlled shape which is equipped with a mechanical source of oxygen and is designed for the purpose of treating wastewater. Aerated lagoons in Mississippi differ from conventional lagoons in the following ways:

1. The depth is considerably greater; 8 to 12 feet as compared to 4 to 6 feet in a conventional lagoon.
2. A mechanical oxygen source such as a floating aerator is provided.
3. A separate effluent settling basin sized for one (1) to two (2) days detention is required.
4. Chlorination of the final effluent is required.
5. Detention time is usually twelve (12) to eighteen (18) days.

The characteristics of a typical aerated lagoon in Mississippi are shown in Table 5-5.

Just as in a conventional lagoon, the processes of settling and biological stabilization of organic matter occur in an aerated lagoon. The settleable matter in the raw wastewater settles in the aerated lagoon. Any settleable matter produced by the biological activity in the lagoon has an opportunity to also settle in the lagoon and in the separate settling basin which typically follows the aerated cell.

TABLE 5-5
TYPICAL CHARACTERISTICS
OF
AERATED LAGOONS

PARAMETER	TYPICAL VALUE/CONDITION
Primary Oxygen Source	Mechanical Aerators
BOD Loading	250 to 600 Lbs/Day/Acre
Water Depth	8 to 12 Feet*
Detention Time	12 to 18 Days*
Aerator Sizes	8 to 10 HP/Million Gallons
BOD_5 Removal	85 to 95%
TSS Removal	75 to 85%
Levee Freeboard	Minimum of 2 Feet
Levee Width @ Top	Minimum of 10 Feet
Levee Side Slopes	Maximum of 3H:1V
Disinfection of Effluent	Required
Separate Effluent Settling Basin	Required

*NOTE: Conventional lagoons that have been upgraded with the addition of aerators may not comply with these values.

Table 5-6

COMMON OPERATIONAL PROBLEMS IN LAGOONS*

Problem	Indicators/Observations	Probable Cause	Remedies
Water Weeds	1. Weeds provide food for burrowing animals, cause short-circuiting problems, stop wave action so that scum can collect and make a nice home for mosquitoes, and odors develop in the still areas; Duckweed stops sunlight penetration and prevents wind action thus reducing the oxygen in the pond; Root penetration causes leaks in pond seal.	A. Poor circulation, maintenance, insufficient water depth.	1. Pull weeds by hand if new growth. 2. Mow weeds with a sickle bar mower. 3. Lower water level to expose weeds, then burn with gas burner. 4. Allow the surface to freeze at a low water level, raise the water level and the floating ice will pull the weeds as it rises. (Large clumps of roots will leave holes in pond bottom, best results are obtained when weeds are young). 5. Increase water depth to above tops of weeds. 6. Use riprap (Caution: If weeds get started in the riprap they will be difficult to remove but can be sprayed with acceptable herbicides). 7. To control duckweed, use rakes or push a board with a boat, then physically remove duckweed from pond.
Burrowing Animals	1. Burrowing animals must be controlled because of the damage they do to dikes; Rodents such as muskrats and nutria dig partially submerged tunnels into dikes; If the water level is raised, they will burrow further and may go on out the top thus weakening the dike.	A. Bank conditions that attract animals. High population in areas adjacent to ponds.	1. Remove food supply such as cattails and burr reed from from ponds and adjacent areas. 2. Muskrats prefer a partially submerged tunnel, if the water level is raised it will extend the tunnel upward and if lowered sufficiently, it may abandon the tunnel completely. They may be discouraged by raising and lowering the level 6-8 inches frequently over several weeks. 3. If problem persists, check with local game commission officer for approved methods of removal, such as live trapping, etc.
Scum	1. It is necessary to control scum formations to prevent odor problems and to eliminate breeding spots for mosquitoes. Also, sizeable floating rafts will reduce sunlight.	A. Pond bottom is turning over with sludge floating to the surface. Poor circulation and wind action. High amounts of grease and oil in influent will also cause scum.	1. Use rakes, a portable pump to get a water jet or motor boats to break up scum formations. Broken scum usually sinks. 2. Any remaining scum should be skimmed and disposed of by burial or hauled to landfill with approval of regulatory agency.

Table 5-6 (continues)*

Problem	Indicators/Observations	Probable Cause	Remedies
Dike Vegetation	1. High weed growth, brush, trees and other vegetation provide nesting places for animals, can cause weakening of the dike and presents an unsightly appearance. Also may reduce wind action on the pond.	A Poor maintenance.	1. Periodic mowing is the best method. 2. Sow dikes with a mixture of fescue and blue grasses on the shore and short native grasses elsewhere. It is desirable to select a grass that will form a good sod and drive out tall weeds by binding the soil and "out compete" undesirable growth. 3. Spray with approved weed control chemicals. Note: Be sure to check with authorities. Some states do not allow chemical usage. All others require that chemicals be biodegradable. Examples of some herbicides that are used are: i. Dow Dalapon for cattails ii. Dow Silvex for willows and emergent weeds iii. Ortho Endo-thal for suspended weeds iv. Copper sulfate for filamentous algae v. Simazine for weeds 4. Some small animals, such as goats have been used. May increase fecal coliform, especially to the discharge cell. Practice "rotation grazing" to prevent destroying individual species of grasses. An example schedule for rotation grazing in a 3-pond system would be: Graze each pond area for 2 months over a 6-month grazing season.
Insects	1 Insects present in area and larvae or insects present in pond water.	A. Poor circulation and maintenance.	Solution for Mosquito Control 1. Keep pond clear of weeds and allow wave action on bank to prevent mosquitoes from hatching out. 2 Keep pond free from scum. 3. Stock pond with Gambusia (Mosquito Fish). 4. Spray with larvaxide as a last resort. Check with state regulatory officials for approved chemicals. (Some that have been used are Naled, Fenthion and Abate in dosages of 1 mg/l). Solution for Controlling Midges 1. Stock pond with Gambusia 2. Spray with approved insecticide. (Fenthion, Abate and Sursban have been used based on directions on the package).

Table 5-6 (continues)*

Problem	Indicators/Observations	Probable Cause	Remedies
Odors	1. Odors are a general nuisance to the public.	A. The odors are generally the result of overloading, long periods of cloudy weather, poor pond circulation, industrial wastes or ice melt.	1. Use parallel feeding to primary cells to reduce loading, if possible. 2. Apply chemicals such as sodium or ammonium nitrate. Dibrom or Micro-acid to introduce oxygen. Application rate: apply 200 pounds sodium nitrate per million gallons. See literature for rate on succeeding days. Or use 100 pounds sodium nitrate per acre for first day, then 50 pounds per day thereafter if odors persist. Apply in the wake of a motor boat. 3. Install supplementary aeration such as floating aerators, caged aerators, or diffused aeration to provide mixing and oxygen; Daily trips over the lagoon area in a motor boat also helps (Note: Stirring the pond may cause odors to be worse for short periods but will reduce total length of odorous period); care should be taken to prevent disturbing lagoon bottom deposits. 4. Recirculate pond effluent to the pond influent to provide additional oxygen and to distribute the solids concentration; Recirculate on a 1 to 6 ratio. 5. Eliminate septic or high-strength industrial wastes.
Low Dissolved Oxygen	1. A low, continued downward trend in D.O. is indicative of possible impending anaerobic conditions and the cause of unpleasant odors; Treatment becomes less efficient.	A. Poor light penetration, low detention time, high BOD loading or toxic industrial wastes (Daytime D.O. should not drop below 3.0 mg/l during warm months.)	1. Remove weeds such as duckweed if covering greater than 40 percent of the pond. 2. Reduce organic loading to primary cell(s) by going to parallel operation. 3. Add supplemental aeration (surface aerators, diffusers and/or daily operation of a motor boat). 4. Add recirculation by using a portable pump to return final effluent to the head works. 5. Apply sodium nitrate. 6. Determine if overload is due to industrial source and remove it.
Organic Overload	1. Overloading which results in incomplete treatment of the waste; Overloading problems can be detected by offensive odors, a yellow green or gray color; Lab tests showing low pH, D.O. and excessive BOD loading per unit area should also be considered.	A. Short-circuiting, industrial wastes, poor design, infiltration, new construction (service area expansion), inadequate treatment and weather conditions.	1. Bypass the cell and let it rest, if possible. 2. Use parallel operation, if possible. 3. Apply recirculation of pond effluent.

Table 5-6 (continues)*

Problem	Indicators/Observations	Probable Cause	Remedies
Organic Overload (Cont)			4. Look at possible short circuiting. 5. Install supplementary aeration equipment.
Decreasing pH	1. pH controls the environment for algae types; pH should be on the alkaline side, preferably about 8.0 to 8.4; Both pH and D.O. will vary throughout the day with lowest reading at sunrise and highest reading in late afternoon; measure pH same time each day and plot on a graph.	A. A decreasing pH is followed by a drop in D.O. as the green algae die off; this is most often caused by overloading, long periods of adverse weather or higher animals, such as Daphnia, feeding on the algae.	1. Bypass the cell and let it rest, if possible. 2. Use parallel operation, if possible. 3. Apply recirculation of pond effluent. 4. Check for possible short circuiting. 5. Install supplementary aeration equipment if problemis persistent and due to overloading. 6. Look for possible toxic or external causes of algae die and correct at source.
Excess Algae in Effluent	1. Most of the suspended solids present in a pond effluent are due to algae; because many single-celled algae are motile and are also very small they are difficult to remove.	A. Weather to temperature conditions that favor particular population of algae.	1. Draw off effluent from below the surface by use of a good baffling arrangement. 2. Use multiple ponds in series, if possible. 3. The use of intermittent sand filters and submerged rock filters may also be used but will require modification and the services of a consulting engineer. 4. In some cases, alum dosages of 20 mg/l has been used in final cells used for intermittent discharge to improve effluent quality; dosages at or below this level are not toxic.
High BOD in Effluent	1. High BOD concentrations that are in violation of NPDES or other regulatory agency permit requirements; visible dead algae.	A. Short detention times, poor inlet and outlet placement, high organic or hydraulic loads and possible toxic compounds.	1. Check for collection system infiltration and eliminate at source. 2. Use portable pumps to recirculate the water. 3. Add new inlet and outlet locations. 4. Reduce loads due to industrial sources if above design level. 5. Prevent toxic discharges.

Table 5-6 (continues)*

Problem	Indicators/Observations	Probable Cause	Remedies
Short-Circuiting	1. Odor problems, low D.O. in parts of the pond, anaerobic conditions and low pH found by checking values from various parts of the pond and noting on a plan of the pond; differences of 100 percent to 200 percent may indicate short-circuiting; after recording the readings for each location, the areas that are not receiving good circulation become evident; these areas are characterized by a low D.O. and pH.	A. Poor wind action due to trees or poor arrangement of inlet and outlet locations; may also be due to shape of pond, weed growth or irregular bottom.	1. Cut trees and growth at least 500 feet away from pond if in direction of prevailing wind. 2. Install baffling around inlet location to improve distribution. 3. Add recirculation to improve mixing. 4. Provide new inlet/outlet locations, including multiple inlets. 5. Clean out weeds. 6. Fill in irregular bottoms.
Anaerobic Conditions	1. Facultative pond that turned anaerobic resulting in high BOD, suspended solids and scum in the effluent in continuous discharge ponds; unpleasant odors, the presence of filamentous bacteria and yellowish-green or gray color and placid surface indicate anaerobic conditions.	A. Overloading, short circuiting, poor operation or toxic discharges.	1. Change from a series to parallel operation to divide load, if possible; helpful if conditions exist at a certain time each year and are not persistent. 2. Add supplemental aeration if pond is continuously overloading. 3. Change inlets and outlets to eliminate short circuiting. 4. Add recirculation (temporary-use portable pumps) to provide oxygen and mixing. 5. In some cases temporary help can be obtained by adding sodium nitrate. 6. Eliminate sources of toxic discharges.
Blue-Green Algae	1. Low pH (less than 6.5) and dissolved oxygen (less than 1 mg/l); foul odors develop when algae die off.	A. Blue-green algae is an indication of incomplete treatment overloading and/or poor nutrient balance.	1. Apply 3 applications of a solution of copper sulfate. i. If the total alkalinity is above 50 mg/l apply 10 pounds of cooper sulfate per million gallons in cell. ii. If alkalinity is below 50 mg/l reduce the amount of cooper sulfate to 5 pounds per million gallons. 2. Break up algal blooms by motor boat or a portable pump and hose; motor boat motors should be air cooled as algae may plug up water cooled motors.

*Source: "Operations Manual for Stabilization Ponds," U.S. EPA 430/9-77-012, August 1977.

Biological stabilization of organic matter in an aerated lagoon is achieved by bacteria just as occurs in a conventional lagoon except that the process is not dependent on algal photosynthesis for an oxygen source. Instead of depending on algae for the production of oxygen, a floating aerator or other aeration device provides oxygen. The aeration devices are usually sized to provide sufficient mixing to disperse oxygen throughout the lagoon. Such mixing generally will require 8 to 10 horsepower per million gallons of water and does not result in complete suspension of solids as exists in the aeration tank of an activated sludge system. Only dispersion of oxygen is achieved in a properly designed aerated lagoon. Some oxygen production due to algal photosynthesis occurs in an aerated lagoon; but the primary source of oxygen is the aeration equipment.

Because of the aeration equipment, an aerated lagoon will have a continuous and more consistent oxygen source, which results in a higher quality effluent. The aeration equipment provides more "control" of the process than exists with a conventional lagoon. Timing devices are often provided with the aeration equipment so that the operator can adjust the "run time" and subsequent oxygen production as needed to maintain the desired effluent quality.

An aerated lagoon is considered to be a facultative process. Just as in a conventional lagoon, the bottom sludge layer in an aerated lagoon is anaerobic and the upper zone is aerobic. Anaerobic decomposition of settled solids occurs in the bottom sludge layer and results in the production of gases such as methane (CH_4), carbon dioxide (CO_2), and ammonia (NH_3). The upper reaches are aerobic. The combination of both aerobic and anaerobic conditions make it possible for facultative bacteria to survive and implement the stabilization of organic matter.

Most aerated lagoons are constructed of rectangular shapes with length to width ratios of less than 2. The major components in an aerated lagoon in Mississippi include the following:

1. Inlet Pipe - The raw wastewater is usually discharged out in the center portion of the lagoon away from the immediate proximity of any sides or corners. Discharge is usually about mid-depth or deeper. Cast iron and ductile iron pipe are the most common materials for inlet pipes.

2. Aeration Equipment - Floating high-speed electric-powered mechanical aerators are the most commonly used aeration equipment. These devices are usually sized to provide 8 to 10 horsepower per million gallons of lagoon volume. They normally are moored with cables and are located over a concrete pad which serves to prevent scouring of the lagoon bottom. Control devices are usually located on or near the lagoon levee for easy access by the operator.

3. Effluent Settling Basin - A small settling basin sized for approximately one (1) to two (2) days detention usually follows an aerated lagoon. This basin allows any settleable matter which has been produced by the processes in the aerated lagoon to settle out prior to discharge.

4. Disinfection Facilities - Effluent disinfection is required in aerated lagoons. This is typically achieved with a separate chlorination facility or ultraviolet system (Refer to Chapter 7).

5. Outlet Structure - The effluent from an aerated lagoon is usually discharged through an outlet structure located on one side of the lagoon or settling basin. This structure typically includes a skimming device and a flow-measuring weir.

6. Lagoon Levees - Aerated lagoons should be diked with continuous levees which prevent surface run-off from entering the lagoon and protect it from floodwaters.

Exhibit 5-6 depicts aerated lagoons presently in operation in Mississippi.

CONVENTIONAL FLOATING AERATOR

BRUSH AERATOR

PUMP AND ASPIRATOR AERATOR

DIFFUSED AERATION

EXHIBIT 5-6

AERATED LAGOONS

b. Process Controls & Performance Indicators

An aerated lagoon generally offers more operational controls than a conventional lagoon, but it is still significantly less controlled than an activated sludge or trickling filter process. The parameters which are most commonly used to control and evaluate the performance of an aerated lagoon include the following:

1. Dissolved Oxygen - It is vital that sufficient oxygen be available for the bacterial stabilization of organic matter. The purpose of the aeration equipment in an aerated lagoon is to supply the needed oxygen. In most instances, the operator of an aerated lagoon should be provided with some means of controlling the "run-time" of the aeration system so that he can provide the amount of oxygen needed. Many aerators are automatically controlled by timing devices.

   There are several methods of monitoring the dissolved oxygen content in an aerated lagoon as a means of determining how much mechanical aeration is needed. These include:

   a. Minimum Dissolved Oxygen - As a general rule, at least 3 mg/l of dissolved oxygen should be maintained. In monitoring the dissolved oxygen, care should be taken to take readings at various depths in the lagoon.

   b. BOD Removal - As a general rule, it is good practice to supply 1.5 times as much oxygen as the desired BOD_5 removal. Most floating aerators can supply approximately 2 pounds of oxygen per horsepower per hour (Lbs/HP/Hour). By computing the influent BOD_5 loading (Lbs/Day) and then applying the desired percent removal, the operator can determine the "Lbs/Day" of oxygen required. Thence, knowing the horsepower and capacity of the aeration equipment, the operator can estimate the amount of "run-time" for the aeration equipment as follows:

      O_2 Req. (Lbs/Day) = BOD Loading(Lbs/Day) x % Removal x 1.5

      $$\text{Run Time (Hrs./day)} = \frac{O_2 \text{ Required (Lbs.Day)}}{\text{Aerator(s) HP x Aeration Capacity (Lbs. } O_2\text{/HP/Hr.)}}$$

   c. Effluent Quality - The operator can monitor the quality of the effluent required by the lagoon's permit and maintain whatever dissolved oxygen level is needed to maintain the desired effluent quality.

2. BOD Loading - The pounds per day of BOD_5 applied to an aerated lagoon is the major parameter that determines the amount of oxygen which the aeration equipment is required to supply. The surface loading on an aerated lagoon can vary significantly depending on its depth, but generally will range from 250 to 600 Lbs/Day/Acre.

3. Detention Time - The desirable detention time in a typical aerated lagoon is usually in the range of twelve (12) to eighteen (18) days based on average daily design flow. Detention time can be computed by dividing the volume of the lagoon by the flow to the lagoon.

   $$\text{Detention Time (Days)} = \frac{\text{Volume of Lagoon (MG)}}{\text{Flow to Lagoon (MGD)}}$$

   Most aerated lagoons in Mississippi are designed to operate at a specified detention time to achieve a desired BOD removal. As a general rule, a detention time of 12 days will theoretically yield 85% BOD_5 removal and 18 days will yield 90% BOD_5 removal.

4. Temperature - Temperature is important to the performance of an aerated lagoon for two reasons. First, the water in a lagoon will hold more oxygen (O_2) per unit volume at a cold temperature than it will at a warmer temperature. Secondly, biological activity decreases with temperature. For example, a 10 degree drop in temperature can reduce bacterial activity by fifty percent (50%).
5. Nutrients - In addition to organic matter and oxygen (O_2), the bacteria in a lagoon need a sufficient supply of nutrients to survive. Nitrogen in the form of ammonia (NH_3) and phosphorus in the form of phosphate (PO_4) are the main nutrients needed. Domestic wastewater normally will have sufficient quantities of each, but occasional monitoring of the influent and lagoon contents is considered good practice.
6. Flow - Flow is a very important parameter in monitoring the performance of an aerated lagoon. In most instances, effluent flow is measured at the outlet structure by means of a weir. Regular flow monitoring is needed for several reasons which include:
    a. It is required for NPDES permit compliance.
    b. Accurate flow data is needed to calculate BOD loadings.
    c. Records compiled from regular flow monitoring will serve as a basis for evaluating the amount of infiltration/inflow which occurs. Over a reasonable period of time, an operator can estimate the amount of infiltration/inflow which is contributed by certain amounts of rainfall.
    d. Effluent quality and performance can be related to flow if accurate flow records are maintained. This will allow the operator to evaluate the effects of high and low flows on effluent quality and may even serve as a basis for adjustments in the "run time" of aerators.

The use of the above-cited parameters as meaningful tools in operating an aerated lagoon is dependent on the individual operator. In essence, all of the parameters, except for adjustment of the dissolved oxygen content, serve more as "indicators" rather than "controls". It is the judgment and action of the operator in responding to these indicators that can make a difference in the performance of an aerated lagoon.

c. <u>Laboratory Controls</u>

Laboratory analyses of collected samples are essential for the proper evaluation and control of the performance of any wastewater treatment facility. Laboratory tests are used to determine process efficiency; evaluate performance; analyze waste strength and characteristics; and trace, identify, and evaluate operational problems.

The first step in compiling good laboratory test results is the collection of good samples. It is important that a sample be as representative as possible of the conditions which it is intended to reflect. Sampling locations in an aerated lagoon are typically confined to the influent and effluent and occasionally to the lagoon itself. Two (2) types of samples can be collected. One is a "grab" sample which consists of a single portion taken at a given time. Grab samples are usually used to measure such parameters as temperature, pH, and dissolved oxygen. The other type of sample is a "composite" sample and consists of portions taken at specific intervals and then combined into a single sample. Composite samples are preferred for such analyses as BOD_5 and total suspended solids.

The most common laboratory analyses and field tests needed for the proper operation and control of an aerated lagoon include the following:

1. 5-day Biochemical Oxygen Demand (BOD_5) - The BOD_5 analysis is typically conducted on the influent and effluent and the results used to determine removal efficiency. Also, the influent results are used to determine the BOD loading on a lagoon.
2. Total Suspended Solids (TSS) - The TSS analysis is typically conducted on the influent and effluent and the results used to determine removal efficiency.

3. Dissolved Oxygen (DO) - The dissolved oxygen content of the lagoon and its effluent should be monitored and correlated with BOD removal results.
4. pH - The pH of the influent, effluent, and lagoon contents should be monitored and correlated with BOD removal results.
5. Temperature - The temperature of the atmosphere and the lagoon contents should be monitored and correlated with BOD removal results.
6. Microscopic Examination - Microscopic examination of the lagoon contents and the receiving stream are often utilized to evaluate the various kinds of microorganisms which are present. Such examination is frequently helpful in identifying the type(s) of algae present in an aerated lagoon.
7. Nutrient Content - When the need arises, it sometimes is necessary to evaluate the nutrient content in an aerated lagoon. This usually involves conducting analyses for ammonia, nitrates, and phosphates.

d. Common Operational Problems

Inherent with any wastewater treatment process are various operating problems which can produce undesirable situations ranging from nuisance conditions to violation of Federal and State pollution control requirements. It is inevitable that an aerated lagoon will experience operational problems, and it is this inevitability which justifies the need for competent and qualified operating personnel.

Before an operational problem can be solved, it must first be identified. Once it has been identified, further investigation can be made as needed to define specific causes and decide upon corrective measures. Investigation of a problem can range from a simple visual observation to detailed and precise laboratory analyses.

Except for the additional problems associated with maintaining aeration equipment, the problems commonly experienced with aerated lagoons are virtually the same as those encountered with conventional lagoons which have been presented previously in Table 5-5. Aeration Equipment should be maintained in strict conformance with the manufacturer's recommendations.

5-5 ANAEROBIC LAGOONS

An anaerobic lagoon is designed to treat wastes with high biochemical oxygen demands such as those from slaughterhouses or meat/poultry processing plants. As the name implies, an "anaerobic" lagoon is one in which dissolved oxygen is not present. Anaerobic bacteria degrade the organic matter and produce such gases as methane (CH_4) and hydrogen sulfide (H_2S). The degradation process takes place in two (2) anaerobic processes. The first involves the conversion of organic matter into acids and ammonia by "acid forming" bacteria. The second process involves the conversion of the acids and ammonia into gases such as methane (CH_4) by a group of bacteria called "gas formers". The gas forming bacteria are sensitive to pH and temperature and consequently, the anaerobic lagoon process as a whole is dependent on and sensitive to these parameters.

Anaerobic lagoons are typically ten (10) to fifteen (15) feet deep and are characterized by a thick scum layer or surface crust. Frequently, anaerobic lagoons are used as a "roughing" stage of treatment preceding an aerobic or facultative process such as activated sludge or a trickling filter. In such installations, the anaerobic lagoon reduces the high-strength waste to a level comparable to domestic strength wastewater.

Table 5-7 lists the typical characteristics of anaerobic lagoons.

TABLE 5-7

TYPICAL CHARACTERISTICS
OF
ANAEROBIC LAGOONS

PARAMETER	TYPICAL VALUE/CONDITION
BOD Loading	15 to 20 Lbs/Day/1000 CF
Depth	10 to 15 Feet
Detention Time	Minimum of 4 Days
BOD_5 Removal	75 to 85%
Desired Operating Temperature	Minimum of 75˚F
Thickness of Scum Layer	2 to 6 Feet
Levee Freeboard	Minimum of 2 Feet
Levee Width @ Top	Minimum of 10 Feet
Levee Side Slopes	Maximum of 3H:1V
Treatment of Effluent	Conventional Biological Treatment Required

EXHIBIT 5-6A

ANAEROBIC LAGOONS

5-6 TRICKLING FILTERS

a. Process Description

The trickling filter process was first used in this country in 1908. It continues to be a widely-used biological treatment process because it is relatively inexpensive to operate and it offers a reliable degree of treatment. The process gets its name from the fact that the wastewater "trickles" down and through a bed of rock or other material which resembles a "filter" in appearance. However, the term "filter" is, in reality, inaccurate because the treatment provided is achieved by biological activities rather than a filter process.

The process utilizes a bed of inert media on which a biological slime growth develops. Wastewater is applied at the surface of the media and it "trickles" over and through the voids of the media. Conversion of organic matter into various gases and cell tissue occurs when the wastewater is absorbed into the slime growth. At the same time that the wastewater is absorbed into the growth, dissolved oxygen made available by the "trickling" or splashing action is also absorbed into the slime growth. The slime growth typically includes a wide variety of microorganisms which include algae, bacteria, fungi, and protozoa. In addition, higher life forms such as worms, snails, and insect larvae are commonly found. The vast majority of the "biological treatment" is achieved by bacteria.

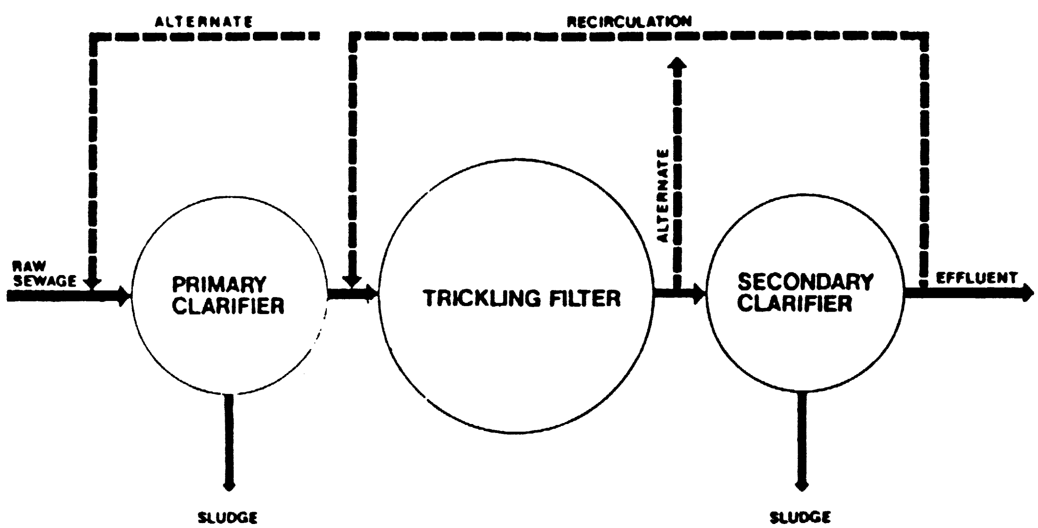


EXHIBIT 5-7

TYPICAL TRICKLING FILTER PROCESS

Source: "Process Control Manual for Aerobic Biological Wastewater Treatment Facilities" U.S. EPA, 430/9-77-066, March 1977

EXHIBIT 5-8

TRICKLING FILTERS

As the wastewater trickles downward through the media and is absorbed into the slime growth, the biological activity results in new cell tissue being produced which in turn causes the slime growth to increase in size. The size and weight of the slime growth eventually increases to the point that the hydraulic action of the wastewater trickling over it will cause portions of the growth to slough off the media. These pieces of slime growth which slough off the media represent the cell tissue to which organic matter has been converted. They are commonly called “sloughings” or “filter humus”. The sloughings pass through the media with the wastewater and are collected at the bottom of the filter and transferred to a clarifier. In the clarifier, the sloughings will settle out because of their weight, leaving a clear effluent at the surface which is low in organic content and suspended matter.

As with activated sludge, the trickling filter process provides an environment which allows the biological processes of respiration and synthesis to be controlled. In providing such control, there are four (4) basic components in a typical trickling filter process. These components, which are illustrated in Exhibit 5-7, are as follows:

1. Primary Clarifier - It is necessary that a primary clarifier be provided ahead of a trickling filter to remove large suspended matter that might otherwise fill the media voids and clog the filter.
2. Trickling Filter - The filter is the major component in the process and is the source of biological treatment. Exhibit 5-8 shows two (2) trickling filters in operation at Mississippi facilities. The clarified wastewater from the primary clarifier is distributed over the media and trickles downward through the media where it is absorbed into the slime growth attached to the media. The hydraulic action of the wastewater causes pieces of the slime growth to slough off and fall to the bottom of the filter. The sloughings contain the new cell tissue to which the organic matter has been converted.
3. Secondary Clarifier - The wastewater and sloughings which pass through the filter are transferred to a secondary (final) clarifier. The quiescent (still) conditions in the clarifier allow the sloughings to separate from the treated wastewater by settling. Exhibit 5-9 shows a secondary clarifier in use at trickling filter facility in Mississippi.
4. Recirculation - It is common practice in most trickling filter processes to recirculate the treated wastewater back through the filter before it is finally discharged. Such practice improves treatment efficiency and aids in overall operation. As discussed hereinafter, there are numerous methods of recirculation.

EXHIBIT 5-9

SECONDARY CLARIFIER AT TRICKLING FILTER FACILITY

The basic operational objective in a trickling filter process is to maintain a healthy slime growth on the filter media by controlling the hydraulic and organic loads applied to the filter. If the organic and hydraulic loads are maintained at levels which produce a healthy slime growth, the result of the biological activity will be sloughings that can be removed in a clarifier. In the discussion which follows, there are several parameters presented which can be used as operational tools to maintain the desired conditions.

b. Process Controls & Performance Indicators

The trickling filter process will provide reliable and efficient treatment if proper operation is provided. As a general rule, the operation of a trickling filter process is somewhat less than that required for most activated sludge processes. However, a trickling filter process is equally dependent on qualified operational personnel and procedures if it is to achieve its desired level of treatment. With proper operation, it will provide a consistently high level of treatment. When improperly operated, a trickling filter process can be a continuous source of complicated problems, nuisances, and frustrations. The process is not intended to function efficiently by itself. Instead, the process is based on the need to "control" the natural biological processes of the microorganisms in the slime growth. Such control is provided only through proper operation.

In the operation of a trickling filter process, there are certain parameters which can and should be used to help control the process and to evaluate its performance. These parameters include the following:

1. Recirculation - Recirculation of the wastewater back through the trickling filter is used to improve performance and minimize operational problems. The quantity of wastewater recirculated varies with the loading characteristics of each particular filter, but typically will range from 0.5 to 4.0 times the raw incoming flow. In evaluating recirculated flows, it is common practice to use a "recirculation ratio" which is defined as the ratio of the recirculated flow to the raw wastewater flow. Mathematically the recirculation ratio (R/Q) is computed as follows:

   $$R/Q = \frac{\text{Recirculated Flow}}{\text{Raw Wastewater Flow}}$$

   where both the recirculated flow and the raw flow are expressed in the same units.

   The wastewater recirculated can be either the trickling filter effluent or the final clarifier effluent, or both. The wastewater is typically recirculated either back to the primary clarifier influent or back to the filter influent as illustrated in Exhibit 5-10.

   The ways in which recirculation improves the performance of a trickling filter process include the follows:

   a. Helps maintain slime growths throughout the media,

   b. Aids in reducing septic conditions in the lower zones of the media and in the clarifier,

   c. Dilutes high strength or toxic wastes,

   d. Minimizes the effects of hydraulic and organic shock load,

   e. Improves distribution of wastewater over the media,

   f. Prevents slime growth from drying out during periods of low flow, and

   g. Minimizes odors, ponding, and filter flies by increasing hydraulic loading to enhance sloughing and reduction of slime thickness.

   While the benefits of recirculation easily justify its use, there are certain adverse effects of its use that are possible with which an operator should be aware. These include the following:

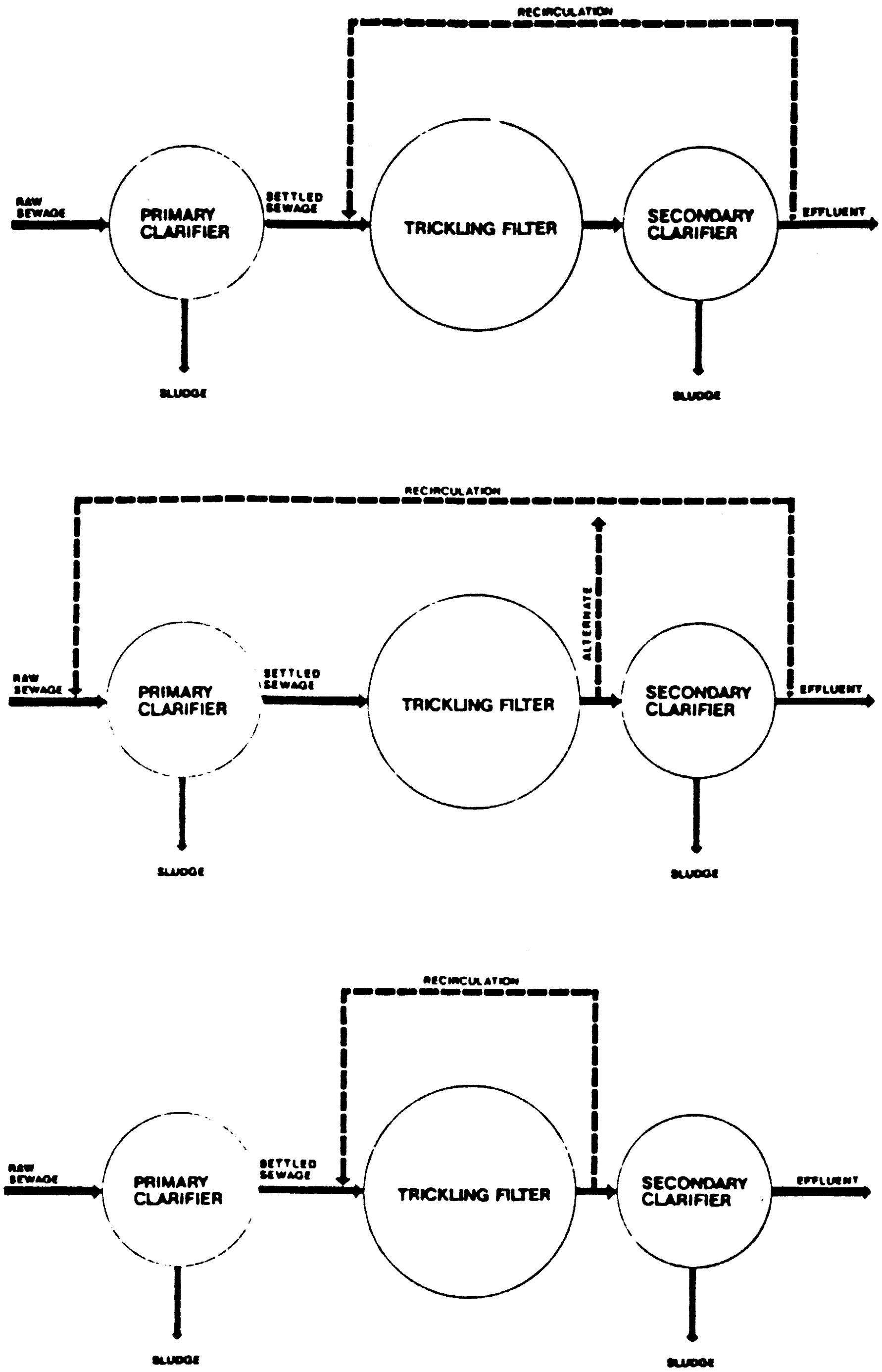


EXHIBIT 5-10

RECIRCULATION SCHEMES IN TRICKLING FILTER PROCESSES

Source: "Process Control Manual for Aerobic Biological Wastewater Treatment Facilities," U.S. EPA, 430/9-77/006, March 1977

a. Wastewater temperature is reduced which in turn reduces the rate of biological activity (this effect is usually not significant except in very cold climates),

b. Excessive recirculation rate can decrease detention time in clarifiers and result in inadequate settling,

c. Recirculation is generally achieved by pumping which increases operational costs, and

d. Excessive recirculation may decrease organic removal efficiency of biological activities in the trickling filter.

2. Sludge Removal - Trickling filter sludge (settled sloughings) generally requires some degree of thickening before being placed in a digester. The most common method of thickening is to return sludge from the secondary clarifier to the primary clarifier for resettling with the raw wastewater. The sludge removed from the primary clarifier is usually sufficiently thickened and can be placed in a digester.

   Sludge withdrawal from the secondary clarifier may be either continuous or on an intermittent basis. However, it is important that the sludge be withdrawn at such a frequency to prevent it from becoming septic. The sludge withdrawal should be increased during periods of heavy sloughings because there is more sludge being produced.

   The sludge produced in a trickling filter system is usually a dark brown humus material which has little or no odor under aerobic conditions. The solids content of trickling filter sludge varies with organic and hydraulic loading conditions, but typically will be less than 2% (20,000 mg/l).

3. Organic Loading - The organic loading is defined as the amount of organic matter, expressed in terms of BOD_5, applied per unit volume of filter media. Mathematically, it is expressed in units of "pounds per day per 1,000 cubic feet" (Lbs/Day/1,000 CF) and computed by dividing the BOD_5 load applied to the filter by the volume of the filter media as follows:

$$\text{Organic Loading} = \frac{BOD_5 \text{ Applied to Filter (Lbs/Day)}}{\text{Volume of Filter Media (1,000 CF)}}$$

   It is common practice to compute organic loading based on the BOD_5 of the raw wastewater applied to the filter (primary clarifier effluent) and to exclude the BOD_5 of any recirculated flow.

   Typical values of organic loadings will range from 5 to 25 Lbs/Day/1,000 CF in low-rate filters, 25 to 100 Lbs/Day/1,000 CF in high-rate filters, and greater than 100 Lbs/Day/1,000 CF in roughing filters.

4. Hydraulic Loading - The hydraulic loading is defined as the flow applied per unit of surface area of filter media. Mathematically, it is usually expressed in units of "gallons per day per square foot" (GPD/SF) and computed by dividing the total flow applied to the filter by the surface area of the filter media as follows:

$$\text{Hydraulic Loading} = \frac{\text{Total Flow to Filter (GPD)}}{\text{Surface Area of Media (SF)}}$$

   where the total flow applied to the filter is the sum of the raw flow and any recirculated flow. Occasionally, the hydraulic loading will be expressed in units of "million gallons per day per acre" (MGD/Ac.) instead of GPD/SF.

   Typical values of hydraulic loadings will vary from 25 to 100 GPD/SF for low-rate filters, 100 to 1,000 GPD/SF for high-rate filters, and 700 to 3,000 GPD/SF for roughing filters.

5. Filter Staging - Filter staging is the operation of trickling filters in series as illustrated in Exhibit 5-11. Such practice produces a higher quality effluent, but obviously must be taken into account during the design and layout of a facility so that the required number of filters and clarifiers is provided.

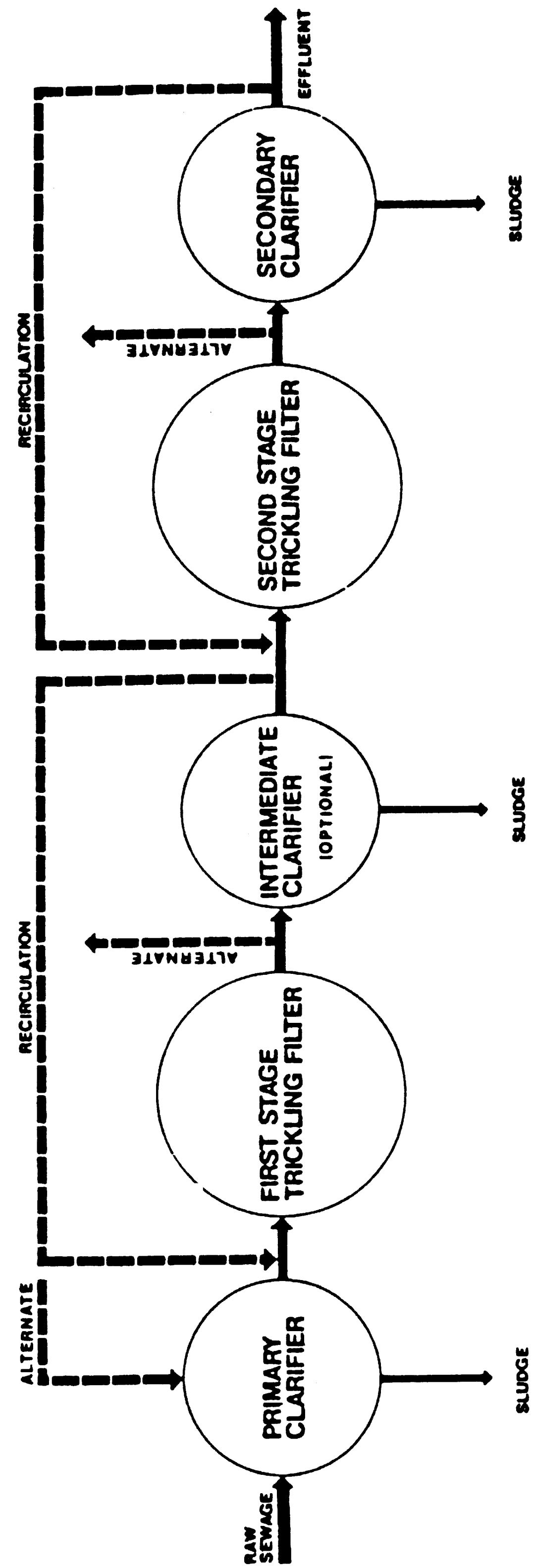


EXHIBIT 5-11
STAGING OF TRICKLING FILTERS
Source: "Process Control Manual for Aerobic Biological Wastewater Treatment Facilities"
U.S. EPA, 430/9-77-006, March 1977

All of the above-cited parameters are related to each other in that a change in one can result in a change in another. The parameters are not within themselves the "answer" to the proper operation of a trickling filter process. Instead, it is the judgement exercised by the individual operator in the interpretation and adjustment of the parameters that will provide the "answers". It is for this reason that competent and qualified personnel are needed to properly operate a trickling filter facility.

c. Filter Components

As previously stated, the trickling filter is the major component in a trickling filter process because it is there that the biological treatment actually occurs. A trickling filter consists of the following three (3) principal components, which are illustrated in Exhibit 5-12:

1. Distribution System - The distribution system distributes the wastewater over the surface of the filter media. This is usually accomplished by rotating distributor arms that are mounted on a turntable assembly anchored to a center column. Exhibit 5-13 contains photographs of rotary distributors in use at trickling filter facilities in Mississippi. The reaction force exerted by the wastewater as it is sprayed from the nozzles on the arms is normally sufficient to rotate the arms. The arms are usually braced by tie rods connected to the center column. These rods need to be adjusted occasionally to maintain the arms in a horizontal position. The arms usually are sized to produce a rotation speed in a range of 0.1 to 2.0 revolutions per minute (RPM).

2. Media - Contrary to its name, filter media does not provide a straining or "filtering" action. Instead, it provides a surface area for the growth of the biological slime which is responsible for the removal of organic matter by converting it to gases and cell tissue (sloughings). Filter media must be durable, insoluble, and uniformly sized. The most common media material is porous rock 3 to 5 inches in size. Other materials which are successfully used includes slag, coal, bricks, redwood blocks, and molded plastic. Media depth for standard-rate and high-rate filters typically range from about 3 to 10 feet. The filter systems depicted in Exhibit 5-13 contain common porous rock media.

3. Underdrain System - The underdrain system of a trickling filter serves the dual purpose of collecting the filter effluent and transferring it to the secondary clarifier and providing adequate circulation (ventilation) of air through the filter media. The system typically consists of floor braces which support the media and a sloped floor which routes the filter effluent into a channel that transfers the effluent to the clarifier.

   The system also consists of vents which allow air to circulate through the filter media to provide the oxygen transfer which is necessary for the aerobic processes to occur. Natural ventilation will occur due to differences in the temperatures of the wastewater and the air. The heating or cooling of the air will cause a density change that results in movement of the air (hot air rises and cool air falls). The direction of air flow through the media will depend on the temperatures of the air and the wastewater. If the wastewater is cooler than the air, air flow will be downward through the media. Conversely, if the wastewater is warmer than the air, the air flow will be upward through the filter.

d. Final Clarifier

Once the wastewater has passed through the filter media, it is transferred to a final (secondary) clarifier. If the biological slime growth is healthy and the hydraulic and organic loadings are in desirable ranges, the filter effluent should contain sloughings which will readily settle out in a clarifier. Thus, it is the function of the final clarifier to provide quiescent (still) conditions which will allow the sloughings to separate from the treated wastewater by settling. The performance of a final clarifier is largely dependent on the condition of the slime growth on the filter media and the hydraulic and organic loads applied to the filter because these factors determine the quantity and quality of the sloughings.

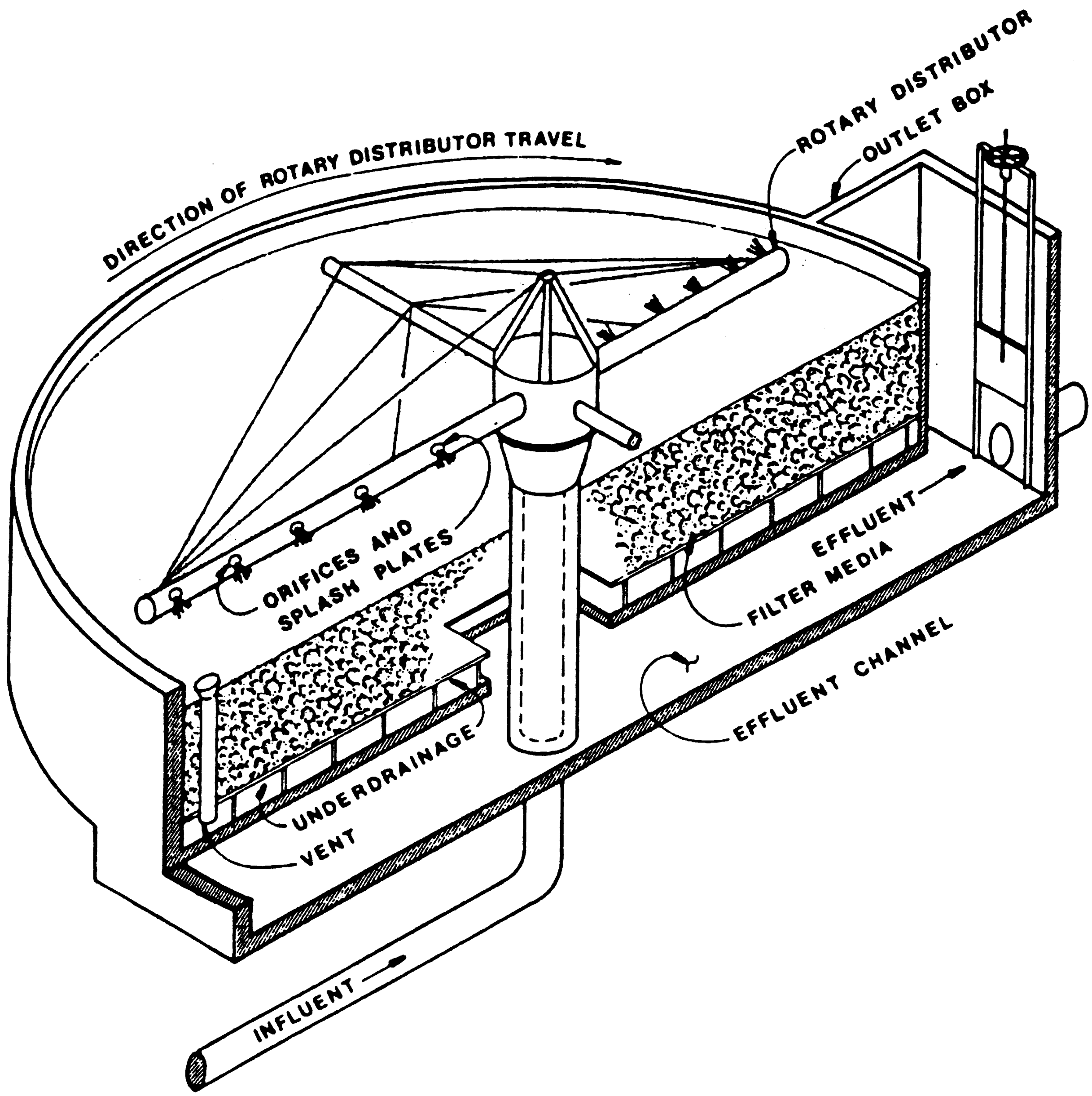


EXHIBIT 5-12

CROSS-SECTIONAL VIEW OF A TYPICAL TRICKLING FILTER

Source: "Process Control Manual for Aerobic Biological Wastewater Treatment Facilities," U.S. EPA, 430/9-77/006, March 1977

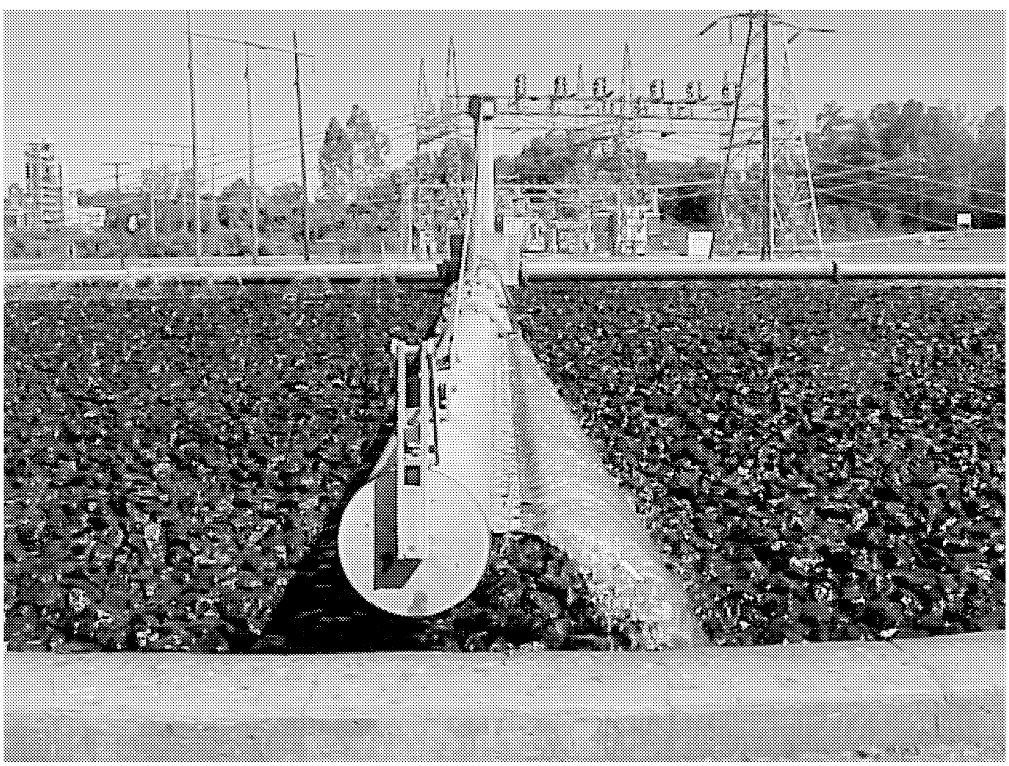


EXHIBIT 5-13

TRICKLING FILTER DISTRIBUTION SYSTEMS

Secondary clarifiers following trickling filters can be either rectangular or circular in shape, although it is more common to find circular shapes. The sloughings settle to the bottom of the clarifier and form "secondary sludge" which is normally removed and mixed with primary sludge before being placed in a digester. Clarified effluent leaves a clarifier, regardless of its shape, by flowing from the surface over a series of weirs. Exhibit 5-14 shows clarified effluent being discharged from a final clarifier at a trickling filter facility. When the clarifier is properly maintained and when conditions in the filter media are such that the sloughings settle easily, the clarified effluent should be low in organic content and suspended matter.

EXHIBIT 5-14

EFFLUENT FROM TRICKLING FILTER SECONDARY CLARIFIER

There are certain parameters which can be used to evaluate the performance of secondary clarifiers in trickling filter processes. These include the following:

1. Surface Loading Rate - Surface loading rate, which is sometimes called "surface overflow rate" or "surface settling rate", is defined as the hydraulic load (gallons per day) applied per unit area (square feet) of clarifier surface. Mathematically, it can be computed as follows:

$$\text{Surface Loading Rate} = \frac{\text{Flow Applied (GPD)}}{\text{Surface Area (SF)}}$$

where the flow applied is the total flow to the clarifier or the sum of the raw wastewater flow and any recirculated flow. Surface overflow rates will typically vary from about 800 to 1,000 GPD/SF.

2. Weir Overflow Rate (WOR) - Weir overflow rate is defined as the hydraulic load (gallons per day) applied per unit length (feet) of effluent weirs. Mathematically, it is computed as follows:

$$WOR = \frac{\text{Flow Applied (GPD)}}{\text{Total Length of Effluent Weirs (Ft.)}}$$

where the flow applied is the total flow or the sum of the raw wastewater plus any recirculated flow. For total flows less than or equal to one (1) million gallons per day (MGD), the WOR should be less than 10,000 GPD/Ft. For total flows in excess of one (1) MGD, the WOR should be less than 15,000 GPD/Ft.

3. Detention Time - Detention time in a final clarifier is the amount of time the filter effluent is allowed to stay in the clarifier for settling. It can be computed by knowing the volume of the clarifier and the flow to the clarifier as follows:

$$\text{Detention Time (Hrs.)} = \frac{\text{Volume (MG) x 24 Hrs./Day}}{\text{Flow (MGD)}}$$

where the flow is the total flow applied or the sum of the raw wastewater flow plus any recirculated flow. Most secondary clarifiers in trickling filter systems are designed to provide three (3) to five (5) hours detention at average daily flow.

e. Filter Classifications

The three (3) basic types of trickling filter systems in use today are low-rate, high-rate, and roughing rate. Their classifications vary with loading characteristics and are described in Table 5-8. The high-rate filters are the most commonly used filter system in the treatment of municipal wastes. Roughing-rate filters are typically used ahead of some other treatment systems such as activated sludge or high-rate trickling filter in the treatment of high-strength wastes.

TABLE 5-8

TRICKLING FILTER CLASSIFICATIONS & CHARACTERISTICS

	Classification of Filter		
Parameter	Low-Rate	High-Rate	Roughing Rate
Media Depth (Ft.)	5-10	3-8	10-30
Organic Loading (Lbs. BOD_5/DAY/ 1000 CF)	5-25	25-100	100 Plus
Hydraulic Loading (GPD/SF)	25-100	100-1,000	700-3,000
Recirculation Ratio (R/Q)	Usually Not Provided	0.5-2.0	0.5-4.0
Sloughings	Intermittent, brown in color, well-stabilized	Continuous, brown in color, unstable	Continuous, brown in color, highly unstable
Secondary Clarifier Surface Loading Rate (GPD/SF)	1,000	800	1,000 (if included)
BOD_5 Removal (%)	80-90	65-85	40-70

f. Laboratory Controls

Laboratory analyses of collected samples are essential to the proper evaluation and control of the performance of any wastewater treatment facility. This is particularly true for a biological treatment process such as a trickling filter. Laboratory tests are used to determine process efficiency; evaluate performance; analyze waste strength and characteristics; evaluate slime growth characteristics; and trace, identify, and evaluate operational problems.

The first step in compiling good laboratory test results is the collection of good samples. It is important that a sample be as representative as possible of the conditions which it is intended to reflect. Sampling locations depend upon the layout and design of each particular treatment facility. Two (2) types of samples can be collected. One is a "grab" sample which consists of a single portion collected at a given time. The other type, which is generally preferred, is a "composite" sample and consists of portions taken at specific intervals and then combined into a single sample.

The most common laboratory analyses and field tests which are typically needed for the proper operation and control of trickling filter processes include the following:

1. Total Suspended Solids (TSS) - This test should be conducted on samples of the raw influent, primary effluent, filter effluent, final effluent, secondary sludge, and primary sludge.
2. Volatile Suspended Solids (VSS) - This analysis should be conducted on the raw influent, secondary sludge, and primary sludge.
3. 5-Day Biochemical Oxygen Demand (BOD_5) - The BOD_5 analysis should be conducted on the raw influent, primary effluent, and final effluent. The results are used to determine removal efficiencies and organic loading.
4. Settleable Solids - This test should be conducted on raw influent, primary effluent, and plant effluent to evaluate sludge settling characteristics. This test is a one-hour settling test conducted with the use of an Imhoff cone.
5. pH - The pH of raw influent, filter effluent, and final effluent should be monitored.
6. Temperature - The atmospheric temperature is usually monitored and correlated with BOD_5 removal results.
7. Microscopic Examination - Microscopic examination of the slime growth, final clarifier effluent, and the receiving stream are often utilized to evaluate the various kinds of microorganisms which are present.

g. Common Operational Problems

Inherent with any wastewater treatment process are various operating problems which can produce undesirable situations ranging from nuisance conditions to violation of Federal and State pollution control requirements. It is inevitable that a trickling filter facility will experience occasional operational problems and it is this inevitability which justifies the need for competent and qualified operating personnel.

Before an operational problem can be solved, it must first be identified. Once it has been identified, further investigation can be made as needed to define specific causes and decide upon corrective measures. Investigation of a problem can range from a simple visual observation to detailed and precise laboratory analyses.

Some of the common problems, along with their causes and cures, that are typically encountered at trickling filter facilities are presented in Table 5-9.

5-7 ROTATING BIOLOGICAL CONTACTORS

Rotating biological contactors evolved in the 1950's in Germany. A single rotating biological contactor (RBC) is comprised of several closely-spaced circular discs which are typically made of plastic materials such as polyvinyl chloride (PVC) or polystyrene. The discs rotate partially submerged in the wastewater being treated and a biological slime covers the disc surfaces. The process is classified as attached growth and is similar in function to a trickling filter. As the discs are rotated, the biological slime is alternately brought into contact with organic matter in the wastewater being treated and oxygen in the atmosphere. The discs are usually housed in enclosures which have a "quonset hut" appearance as shown in Exhibit 5-15.

The rotating action of the discs serves to create and maintain aerobic conditions by transferring oxygen to the biological slime. In addition to providing a means of oxygen transfer, the rotation of the discs is also the means by which excess biological growths (solids) are removed from the slime. Just as the hydraulic action of wastewater "trickling" through the media of a tricking filter causes that slime to slough, the hydraulic action of the discs rotating through the wastewater causes sloughing of the slime. The sloughings are subsequently routed to a clarifier for settling.

One characteristic of rotating biological contactors that is typically different from the attached growth environment of a tricking filter is the ability to achieve more nitrification with the rotating discs. Such characteristic is attributed to the presence of more biological mass on the discs than would normally be found on trickling filter media, resulting in a lower ratio of organics to microorganisms. This characteristic also permits rotating biological contactors to better withstand hydraulic and organic shock loads.

EXHIBIT 5-15

ROTATING BIOLOGICAL CONTRACTORS

Table 5-9

COMMON OPERATIONAL PROBLEMS IN TRICKLING FILTER PROCESSES*

Problem	Observations	Probable Cause	Necessary Checks	Remedies
Filter Flies	1. Filter flies (gnat-sized moth-like flies) around filter and dark brown, worm-like larvae in filter slime growth.	A. Poor distribution of waste-water, especially along filter wall.	1. Visually check	a. Unclog spray orifices or nozzles b. Provide orifice openings at end of distributor arm to spray walls or open dump gates slightly for a spray effect on filter wall.
		B. Hydraulic loading is in-sufficient to keep fly eggs and larvae washed from filter.	1. Calculate hydraulic loading; Hydraulic loadings greater than 200 GPD/SF are usually required.	a. Prevent completion of the filter fly life cycle in the following order: i. Increase recirculation rate, ii. Flood filter for several hours each week during fly season, iii. Chlorinate filter influent for several hours each week maintaining a 1 to 2 mg/l residual at the distributor outlet.
Odors	1. Odors (Anaerobic decompo-sition within the filter)	A. Excessive organic loading	2. Calculate organic loading.	a. Enhance aerobic conditions in pretreatment units - try pre-chlorination, aeration, or recirculation during low night time flows. b. Improve operation of primary sedimentation tanks. c. Increase recirculation rate to dilute organic strength and improve oxygen transfer. d. Chlorinate filter influent for several hours each day during low flow, maintaining a 1 to 2 mg/l residual at distributor outlet. e. Enforce sewer use ordinance. f. If design loading is being exceeded, plant expansion may be required.

Table 5-9 (continued)

Problem	Observations	Probable Cause	Necessary Checks	Remedies
Odors (cont)		B. Poor Ventilation	1. If provided, see that vent pipes are clear in filter.	a. Unclog vent pipes.
			2. Check underdrain system to see that it is not obstructed or flowing more than half full.	b. Remove all debris from the filter effluent channel and flush obstructive materials from underdrain.
			3. Check filter media voids to see that they are not filled with biological growths or debris.	c. If underdrain system is flowing more than half full, reduce recirculation rate if possible.
				d. Improvise a mechanical means of improving ventilation if natural ventilation is not adequate.
				e. Increase recirculation to flush out excessive biological growths.
		C. Poor housekeeping	1. Visually check	a. Remove all debris from filter media source.
				b. Wash down distributor splash plates and the side walls above the media.
Ponding	1. Ponding of water over filter	A. Excessive biological growth media.	1. Check records for increases in organic loading and/or decreases.	a. Loosen surface layer of rock media.
				b. Flush the ponded area with high pressure stream of water.
				c. Increase recirculation.
				d. Dose the filter influent with chlorine for 2 to 4 hours to obtain 1 to 2 mg/l residual at the distributor outlet.
				e. If possible, flood the filter for 24 hours.
				f. If possible, take filter out of service, dry media and wash out.

Table 5-9 (continued)

Problem	Observations	Probable Cause	Necessary Checks	Remedies
Ponding (cont.)		B. Media is non-uniformly sized, disintegrating or too small.	1. Visually inspect.	a. Dry out filter and check media, replace non-uniform sized or damaged media.
		C. Poor housekeeping	1. Visually inspect.	a. Remove all leaves, paper, sticks and other debris accumulating on filter media surface.
High Effluent Suspended Solids	1. Increase in Clarifier Effluent Suspended Solids.	A. Excessive Sloughing	1. Check seasonal changes that would effect microorganisms.	a. Wait for season to change or try polymer addition to improve setting.
			2. Check organic loading.	b. If loading is excessive, use additional filters if available.
				c. Enforce sewer use ordinance.
				d. Increase sludge withdrawal rate in clarifier.
				e. Plant expansion may be required.
		B. Denitrification in Clarifier	1. Check to see if filter effluent is nitrified and sludge floats (rises) in clumps.	a. Increase sludge withdrawal rate in clarifier.
		C. Final Clarifier is hydraulically overloaded.	1. Calculate clarifier surface loading rate; should not exceed 1,000 GPD/SF at peak flow.	a. If hydraulic overload is due to recirculation, reduce recirculation rate during peak flow periods.
				b. Additional clarifier may be required.
		D. Equipment Malfunction in Clarifier.	1. Check for broken sludge collection equipment.	a. Replace or repair broken equipment.
			2. Check for broken baffles.	b. Adjust effluent weirs to equal elevations.
			3. Check for uneven flows over effluent weirs.	
		E. Temperature currents in final clarifier	1. Make temperature survey of the clarifier using a temperature probe on a D.O. meter.	a. Install baffles to stop short circuiting.

Table 5-9 (continued)

Problem	Observations	Probable Cause	Necessary Checks	Remedies
Freezing	1. Freezing of wastewater on media	A. Low temperatures	1. Check atmospheric temperature	a. Decrease recirculation. b. Operate 2-stage filters in parallel. c. Adjust orifices and splash plate for coarse spray. d. Construct windbreak. e. Partially open dump gates on outer end of distributor arm to provide stream along retaining wall instead of a spray. f. Cover pump stumps and dosing tanks. g. Manually remove ice formations.

*Source: "Process Control Manual for Aerobic Biological Wastewater Treatment Facilities," U.S. EPA-430/9-77-006

5-8 ACTIVATED SLUDGE

a. Process Description

The activated sludge process was originally developed in 1914 in England. It gets its name "activated sludge" because the process produces a biologically active mass of brown floc which is referred to as "sludge". In principle, the process is a very simple one which involves the mixing of wastewater with air (oxygen) for a specified length of time. The process can be illustrated as follows:

$$H_2O + \text{Organic Matter} + \text{Microorganisms} + O_2 \xrightarrow{\text{Mixing}} \text{Activated Sludge.}$$

In the preceding illustration, the first three ingredients (water, organic matter and microorganisms) are all natural constituents of domestic wastewater. The fourth ingredient, which is oxygen, is supplied at the treatment plant along with provisions for "mixing" the four ingredients together, which results in the formation of the floc or sludge particles. As previously discussed in this chapter, biological treatment involves the removal of organic matter by converting it to various gases and cell tissue. The floc particles produced by mixing air (oxygen) and wastewater is in fact the cell tissue produced by the biological process of synthesis. The mass of floc thus produced by the biological process is heavier than water and is collectively referred to as "activated sludge". When placed in a clarifier, the floc or "activated sludge" will settle by gravity leaving a clear liquid low in organic content and suspended matter.

An activated sludge process provides an environment whereby the natural biological processes of respiration and synthesis can be controlled. In providing such control, there are four (4) basic components which comprise every activated sludge process. These components, which are illustrated in Exhibit 5-16, are as follows:

1. Aeration - The untreated wastewater enters the aeration tank where air is injected into the tank by either diffused or mechanical means. As the air is added, the contents of the tank are also mixed. It is in the aeration tank that the "biological" treatment actually occurs; i.e. the organic matter is converted to gases and cell tissue (floc). The contents of the tank are often referred to as "mixed liquor" and the quantity of floc produced is measured in terms of the suspended solids content or "mixed liquor suspended solids" (MLSS). Exhibit 5-17 contains photographs of aeration tanks in operation at various activated sludge facilities in Mississippi.
2. Sedimentation - As previously described, the cell tissue (floc) produced by the biological stabilization of organic matter is heavier than water. Thus, when the mixed liquor is transferred from the aeration tank to a settling tank where quiescent (still) conditions exist, the floc will settle out, leaving a clear liquid at the surface to be discharged. The clarifier to which the mixed liquor is transferred is commonly referred to as a "secondary" or "final" clarifier. The role of such a clarifier is the removal (by settling) of the floc or activated sludge particles produced in the aeration tank. The performance of the clarifier is virtually dependent on the conditions which exist in the aeration tank and the quality and quantity of floc produced therein. Exhibit 5-18 shows two clarifiers in operation at activated sludge facilities in Mississippi.
3. Return Sludge - As the sludge particles in the mixed liquor settle to the bottom of the clarifier, it is collected and removed. A portion of this settled sludge is returned to the aeration tank for the purpose of maintaining balanced conditions therein. The quantity and frequency of the sludge returned varies according to individual process needs and operational techniques. In fact, the practice of returning

sludge is perhaps the most influential operational tool available to an operator in controlling an activated sludge process. Exhibit 5-19 shows sludge being returned to an aeration tank at an activated sludge facility in Mississippi.

4. Waste Sludge - The settled sludge in the clarifier which is not needed as return sludge must be removed or "wasted" from the system. Sludge is normally wasted to a digester for separate stabilization. Because activated sludge is a biological process in which new cell tissue is virtually always being produced, it is only natural that an excess of floc (cell tissue) will eventually be produced. The term "excess" is defined as that which is not needed to maintain desired conditions in the aeration tank.

The basic objective in the operation of an activated sludge process is to maintain balanced conditions in the aeration tank. The parameters which must be balanced are the amount of food or organic content and the amount of microorganisms. Organic content is normally measured in terms of biochemical oxygen demand (BOD) and microorganisms are usually measured in terms of the volatile portion of the mixed liquor suspended solids. The mixed liquor suspended solids contain both active (volatile) and inert solids. It is the volatile solids which are biologically active in stabilizing organic matter. If the amount of food (organic matter) and the amount of microorganisms available to consume that food are properly balanced, then the result of the biological activity will be a good-settling sludge that can be easily removed in the clarifier, leaving a clear supernatant. In the discussion which follows, there are several parameters presented which can be used as operational tools to maintain the desired conditions.

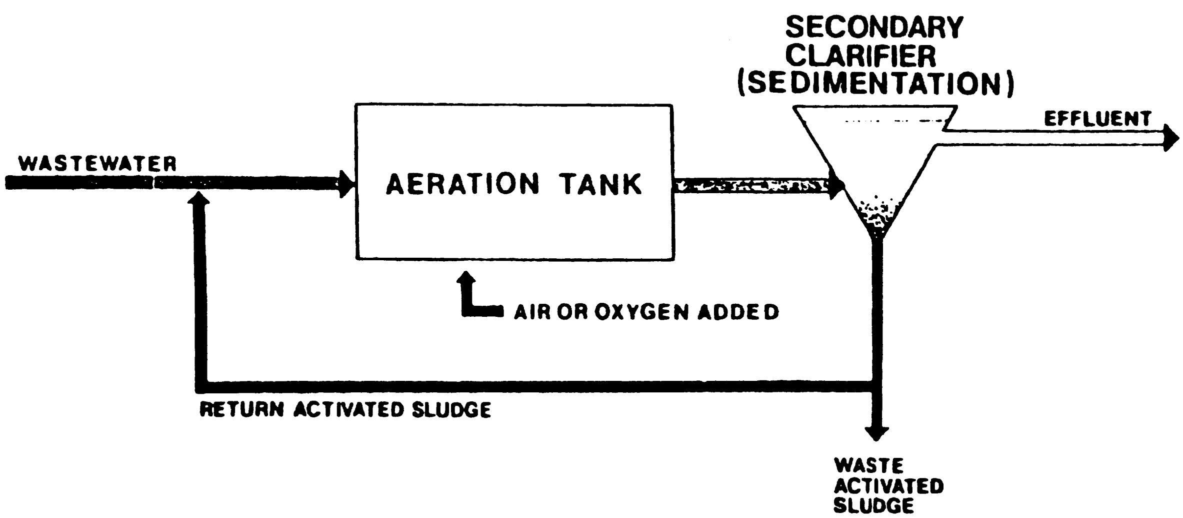


EXHIBIT 5-16

SCHEMATIC DIAGRAM OF TYPICAL ACTIVATED SLUDGE PROCESS

Source: "Process Control Manual for Aerobic Biological Wastewater Treatment Facilities" U.S. EPA, 430/9-77-006, March 1977.

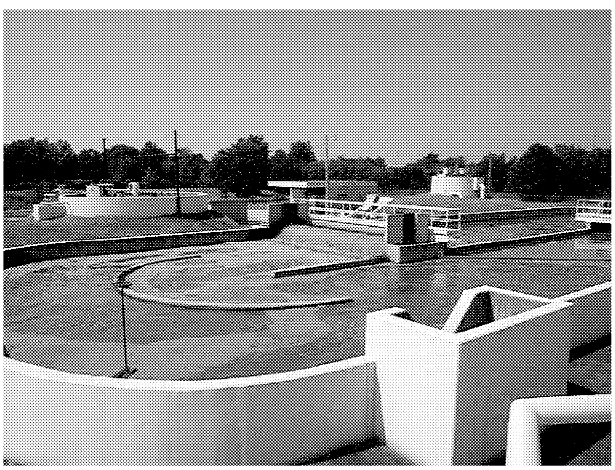
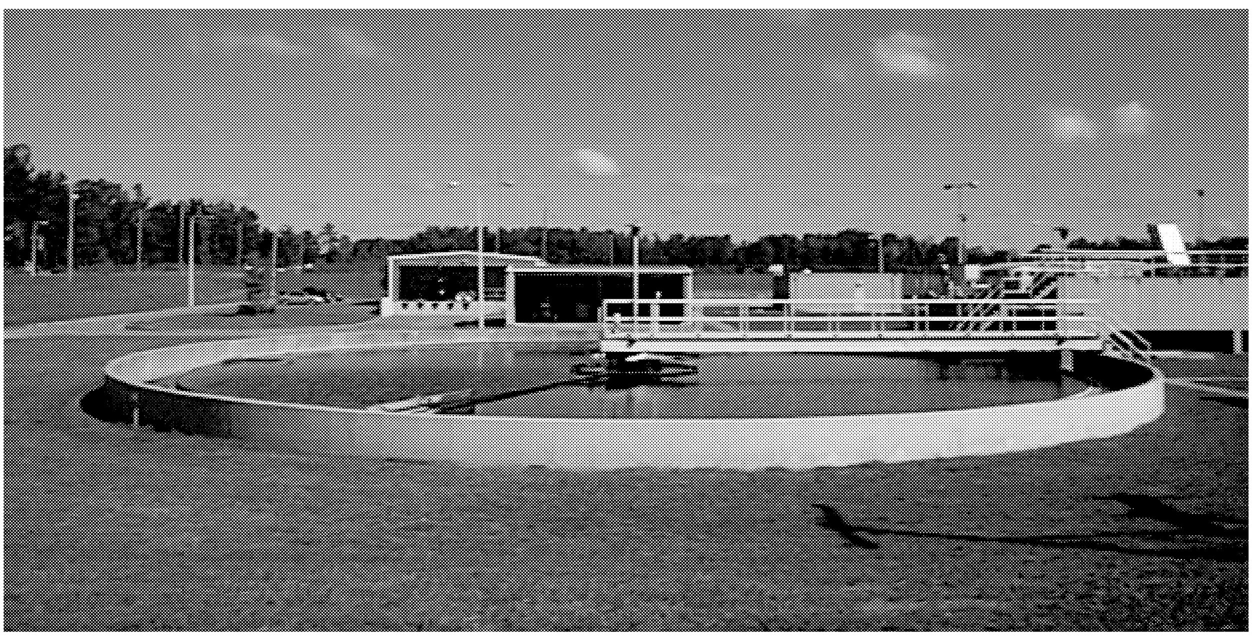


EXHIBIT 5-17

ACTIVATED SLUDGE AERATION BASINS

RECTANGULAR SECONDARY CLARIFIER



CIRCULAR SECONDARY CLARIFIER

EXHIBIT 5-18

SECONDARY CLARIFIERS
AT
ACTIVATED SLUDGE FACILITIES

EXHIBIT 5-19

ACTIVATED SLUDGE BEING RETURNED TO AERATION

b. Process Controls and Performance Indicators

The activated sludge process offers both reliability and efficiency if it is properly operated. Perhaps the most important fact to recognize and understand about an activated sludge process is that it must be operated by qualified personnel. When properly operated, it will provide a consistently high level of treatment. When improperly operated, it can be a continuous source of problems, nuisances, and frustrations. The process is not intended to, nor will it, function efficiently by itself. The whole process is premised on the fact that the treatment facility provide a means to "control" the natural biological processes of the microorganisms. Such control is provided only through proper "operation".

In the operation of an activated sludge facility, there are certain parameters which can and should be used to help control the process and to evaluate its performance. These parameters include the following:

1. Dissolved Oxygen Content in Aeration Tank - The activated sludge process is an aerobic process which means that it is absolutely essential that sufficient dissolved oxygen be available in the aeration tank for the microorganisms. As a general rule the dissolved oxygen concentration needs to be maintained in the range of 1.0 to 2.0 mg/l. Supplying about 1.0 to 1.25 pounds of oxygen per pound of BOD_5 removed will typically result in a dissolved oxygen concentration in the desired range. Such a supply is equivalent to about 1,500 to 2,000 cubic feet of air per pound of BOD_5 removed.

2. Organic Loading - The organic loading is defined as the amount of organic matter, expressed in terms of BOD_5, applied per unit volume of aeration tank capacity. Mathematically, it is expressed in units of "pounds per day per 1,000 cubic feet" (Lbs/Day/1000 CF) and computed by dividing the BOD_5 load by the volume of the aeration tank(s) as follows:

$$\text{Organic Loading} = \frac{BOD_5 \text{ Applied to Aeration Tank (Lbs/Day)}}{\text{Volume of Aeration Tank (1000 CF)}}$$

Typical values of organic loadings will range from 10 to 100 Lbs/day/1000 CF depending on the particular type activated sludge process being used. Organic loading is also sometimes called "volumetric loading" or "design loading".

3. Food to Microorganism Ratio (F/M) - The F/M ratio is an indication of the balance which exists between the amount of organic matter (food expressed as BOD_5) and the amount of microorganisms (the volatile portion of the mixed liquor suspended solids) in the aeration tank(s). Mathematically, it is usually expressed without units and can be computed by dividing the BOD_5 load (Lbs/Day) which enters the aeration tank(s) by the amount (Lbs.) of mixed liquor volatile suspended solids (MLVSS) in the aeration tank(s):

$$F/M = \frac{BOD_5 \text{ Entering Aeration Tank (Lbs./Day)}}{\text{MLVSS In Aeration Tank (Lbs.)}}$$

The F/M ratio can be adjusted by returning and/or wasting sludge. It can be increased by returning less sludge (or wasting more). Conversely, it can be decreased by returning more sludge (or wasting less). Typical values of F/M ratios vary considerably with individual processes, but will typically range from 0.05 to 0.60.

4. 30-Minute Settleability/Settlometer - The 30-minute settleability test is conducted on a sample of the mixed liquor suspended solids (MLSS). It serves as an indicator of the sludge settling and compaction characteristics. The test is simply performed by transferring a thoroughly-mixed sample of mixed liquor into a 1,000 ml graduated cylinder and then recording the milliliters of settled sludge after thirty (30) minutes. The results can be recorded in units of "ml/l" or "%". Typical values for good settling sludges range from 100 to 700 ml/l or 10% to 70%.

The Settlometer test is similar to the 30 Minute setting test except that a large diameter, 2 liter vessel is used instead of a 1000 ml graduated cylinder. Also, the MLSS are allowed to settle for one (1) hour with the settling rate plotted on graph paper. Settling rates are plotted at five (5) minute intervals for 30 minutes and at ten (10) minute intervals for the remainder of the hour. This test provides a good visual indicator of the sludge settling characteristics.

5. Sludge Volume Index (SVI) - The sludge volume index (SVI) is used as a means of evaluating sludge settling characteristics. It is defined as the volume (ml) occupied by one gram of activated sludge (MLSS) after thirty (30) minutes of settling. Mathematically, it is expressed in units of milliliters per gram (ml/g) although it is typically reported without units. SVI is computed as follows:

$$SVI = \frac{\text{Volume of Settled Sludge @ 30 Minutes(ml/l) x 1,000 mg/g}}{\text{MLSS (mg/l)}}$$

where the volume of settled sludge is obtained from conducting a 30-minute settleability test in a standard 1,000 ml graduated cylinder. Typical SVI values for a "good settling sludge" will normally range between 70 to 120.

6. Sludge Age or Mean Cell Residence Time (MCRT) - Sludge age is a ratio of the amount of mixed liquor suspended solids (MLSS) in the aeration tank(s) to the amount of total suspended solids (TSS) which enter the aeration tank(s) per day. It is a means of evaluating the balance between the incoming solids and the mixed liquor solids. Mathematically, it is normally expressed in units of "days" and can be computed as follows by dividing the amount (Lbs.) of MLSS in the aeration tank(s) by the amount (Lbs/Day) of TSS entering the aeration tank(s) each day:

$$\text{Sludge Age (Days)} = \frac{\text{MLSS in Aeration Tank (Lbs.)}}{\text{TSS Entering Aeration Tank (Lbs./Day)}}$$

The conversion of ammonia nitrogen (NH_3/NH_4+) to nitrate nitrogen (NO_3-) which occurs during an activated sludge process is directly dependent on sludge age. A longer sludge age will result in conversion of ammonia (NH_3) to nitrate (NO_3-). Sludge ages typically vary from a low of about 3 days to a high of about 30 days, depending on the individual process.

Another parameter which can be used to evaluate the balance of solids in an activated sludge process is the mean cell residence time (MCRT). The MCRT is expressed in units of "days" and can be computed as follows by dividing the amount (Lbs.) of MLSS in both the aeration tank(s) and final clarifier by the amount (Lbs.) of suspended solids wasted per day and discharged in the effluent per day:

$$\text{MCRT (Days)} = \frac{\text{MLSS(Lbs) in Aeration + MLSS(Lbs) in Clarifier}}{\text{SS Wasted (Lbs/Day) + Effluent SS (Lbs/Day)}}$$

The MCRT represents the average time that a microorganism will stay in an activated sludge system. Typical values of MCRT will usually be in the range of 5 to 15 days. As with sludge age, a longer MCRT will result in more conversion of ammonia nitrogen (NH_3/NH_4-) to nitrate (NO_3-).

7. Return Sludge - A portion of the sludge which settles in a secondary clarifier should be returned to the aeration tank to maintain the mixed liquor suspended solids (MLSS) concentration necessary to keep the F/M ratio within the desired range. Sludge is normally returned on a continuous basis at some selected rate. Sludge return rates can be computed in various ways, depending on which particular control parameter is utilized. The following are three (3) common methods which are frequently used:

   a. MLSS Method - This method is probably the most common and is based on the suspended solids concentrations of the mixed liquor (MLSS) and the sludge being returned. The amount of return sludge at a particular concentration needed to maintain a certain MLSS concentration in the aeration tank(s) is often expressed as a percent of the incoming flow (average daily flow) to the aeration tank(s) as follows:

$$\text{\% Return Sludge} = \frac{\text{MLSS (mg/l) x 100}}{\text{Return Sludge SS (mg/l) - MLSS (mg/l)}}$$

The actual "return sludge rate" in units such as "gallons/day" (GPD) or "million gallons/day" (MGD) can then be computed by multiplying the "% Return Sludge" by the average daily flow:

Return Sludge Rate = % Return Sludge x Average Daily Flow

b. Settleability Method - This method is based on results of the 30-minute settleability test. The % Return Sludge, expressed as a percent of the incoming flow (average daily flow), can be computed as follows:

$$\text{\% Return Sludge} = \frac{\text{Settled Sludge @ 30 Minutes (ml/l) x 100}}{\text{1000 - Settled Sludge @ 30 Minutes (ml/l)}}$$

The actual "return sludge rate" can then be determined as in the MLSS method by multiplying the "% Return Sludge" by the "Average Daily Flow". The settleability method is not always as accurate as the MLSS method because it assumes that the settling which takes place in the 1,000 ml graduated cylinder in the 30-minute settleability test is the same as that which takes place in the clarifier.

c. SVI Method - This method utilizes the Sludge Volume Index (SVI). The calculations are virtually the same as the MLSS method except that the SVI is used to estimate the suspended solids concentration of the return sludge. The "% Return Sludge", expressed as a percent of the incoming flow (average daily flow), can be computed as follows:

$$\% \text{ Return Sludge} = \frac{\text{MLSS (mg/l)} \times 100}{\dfrac{1{,}000{,}000}{\text{SVI}} - \text{MLSS (mg/l)}}$$

The actual "return sludge rate" can then be determined as in the other methods by multiplying the "% Return Sludge" by the "Average Daily Flow".

Return sludge will typically vary from as little as 25% of the incoming flow to as much as 150%. The concentration of the return sludge is usually in the range of 1% to 2% solids (10,000 mg/l to 20,000 mg/l). MLSS concentrations typically vary from 2,000 mg/l to 6,000 mg/l depending on the process and other design considerations.

8. Waste Sludge - Excess sludge which is not needed as return sludge to maintain balanced conditions in the aeration tank must be removed or "wasted" from an activated sludge process. The sludge so wasted is normally transferred to a digester for further stabilization before it is dewatered and disposed of. Wasting can be on a continuous basis or as needed, depending on the conditions at a particular facility. The volume of sludge to be wasted is normally calculated either on the basis of maintaining a desired MLSS concentration in the aeration tank(s) or maintaining a desired mean cell residence time (MCRT). These two methods are described as follows:

   a. MLSS Method - This method is probably the most commonly used. It calls for excess sludge to be wasted when the desired MLSS concentration is exceeded. The volume of excess sludge can be computed as follows:

   $$\text{Waste Sludge (MG)} = \frac{\text{Actual MLSS - Desired MLSS] (mg/l)} \times \text{Aeration Volume (MG)}}{\text{SS in Waste Sludge (mg/l)}}$$

   The "desired MLSS" may be, at the operator's option, that necessary to maintain a desired sludge age or F/M ratio.

   Once the volume (MG) of sludge to be wasted has been calculated, the actual "waste sludge rate" (MGD) at which the sludge is removed is dependent upon the length of time (Hrs.) over which the sludge is to be wasted:

   $$\text{Waste Sludge Rate (MGD)} = \frac{\text{Waste Sludge (MG)} \times \text{24 Hrs./Day}}{\text{Wasting Period (Hrs.)}}$$

   b. MCRT Method - This method determines the amount of sludge to be wasted in order to maintain a desired mean cell residence time (MCRT). In most instances the quantity (Lbs/Day) of waste sludge is first computed as follows:

   $$\text{Waste Sludge (Lbs/Day)} = \frac{\text{MLSS in Aeration \& Clarifier (Lbs)}}{\text{Desired MCRT (Days)}} - \text{Effluent SS (Lbs/Day)}$$

   Once the amount (Lbs/Day) of waste sludge has been determined, the actual "waste sludge rate" (MGD) can be determined as follows:

   $$\text{Waste Sludge Rate (MGD)} = \frac{\text{Waste Sludge (Lbs/Day)}}{\text{SS in Waste Sludge (mg/l)} \times 8.34}$$

   The quantity of excess or waste sludge produced varies significantly with the characteristics of the particular activated sludge process being used. Typical values will range from 0.15 to 0.75 pounds of solids per pound of BOD_5 removed.

9. Aeration Detention Time - The detention time is simply the amount of aeration time to which the raw wastewater is subjected; i.e. the theoretical length of time required from the time the wastewater enters the aeration tank(s) until it leaves. Detention time is usually expressed in units of "hours" and can be computed by dividing the volume of the aeration tank(s) by the average daily flow to the tank(s) as follows:

$$\text{Detention Time (Hrs.)} = \frac{\text{Volume of Aeration (MG)} \times 24 \text{ Hours/Day}}{\text{Avg. Daily Flow (MGD)}}$$

Activated sludge processes are designed to operate at aeration detention times ranging from about three (3) hours to as much as forty (40) hours.

In applying the above-cited parameters to the actual operation of an activated sludge process, it is important to understand that all of the parameters are virtually related and that what affects one can affect any or all of the others. Also, it is necessary to realize that these parameters are, within themselves, not the "answer" to the proper operation of a facility. Instead, it is the judgement exercised by the individual operator in the interpretation and adjustment of these parameters that will provide the "answers"; and it is for this reason that competent and qualified personnel are needed to properly operate an activated sludge facility.

c. Aeration Equipment

Aeration serves a dual purpose in an activated sludge process. First, it supplies oxygen to the microorganisms and secondly, it mixes the contents of the aeration tank. Aeration is usually provided by using one of the following types of aeration equipment:

1. Diffused Aeration - Diffused aeration systems consist of blowers which force air through porous diffusers. The diffusers are usually located at the bottom of the aeration tank. Exhibit 5-17 previously presented, shows some aeration tanks which utilize diffused aeration. Diffusers can be either "fine bubble" or "coarse bubble". Fine bubble diffusers typically result in about 8% of the oxygen supplied being transferred to the wastewater in the aeration tank as compared to about 5% transfer efficiency for coarse bubble diffusers. Fine bubble diffusers tend to clog more easily. Coarse bubble diffusers generally cost less and require less maintenance. Exhibit 5-20 shows blowers utilized in diffused aeration system at various activated sludge systems in Mississippi. Exhibit 5-21 shows diffusers in empty aeration tanks.
2. Mechanical Aeration - Mechanical aeration systems consist of a mixing or pumping mechanism which disperses water drops through the atmosphere. Such devices can be either platform mounted or floating devices as shown in Exhibit 5-22. These devices are generally capable of delivering or transferring about 2 pounds of oxygen per hour per horsepower to the aeration tank contents.
3. Disc or Brush Aerators - Disc and brush aerators are typically used in oxidation ditch systems, which are a modification of the activated sludge process. Their purpose, in addition to providing oxygen and mixing, is to propel the contents through the ditch (aeration tank). Disc aerators are circular in shape and made of a plastic-resin compound. The discs are constructed with holes or knobs which lift the water from the ditch and disperse it through the atmosphere as the disc is immersed and rotated. Brush aerators achieve the same objective by lifting the water with a "brushing" effect as they turn. Exhibit 5-23 shows brush aeration systems in operation.

d. Sedimentation Systems (Secondary Clarifiers)

Once the biological processes have taken place in the aeration tank, the tank contents (mixed liquor suspended solids) are transferred to a secondary clarifier. If the conditions in the aeration tank have been properly maintained, the results will be a mixed liquor from which the sludge will easily settle out in the clarifier. Thus, the function of the clarifier is to provide quiescent (still) conditions which will allow the sludge to separate from the treated wastewater and settle by gravity. It is important to recognize, however, that the performance of the clarifier is largely dependent on the performance of the aeration tank and the quantity and quality of the sludge produced therein.

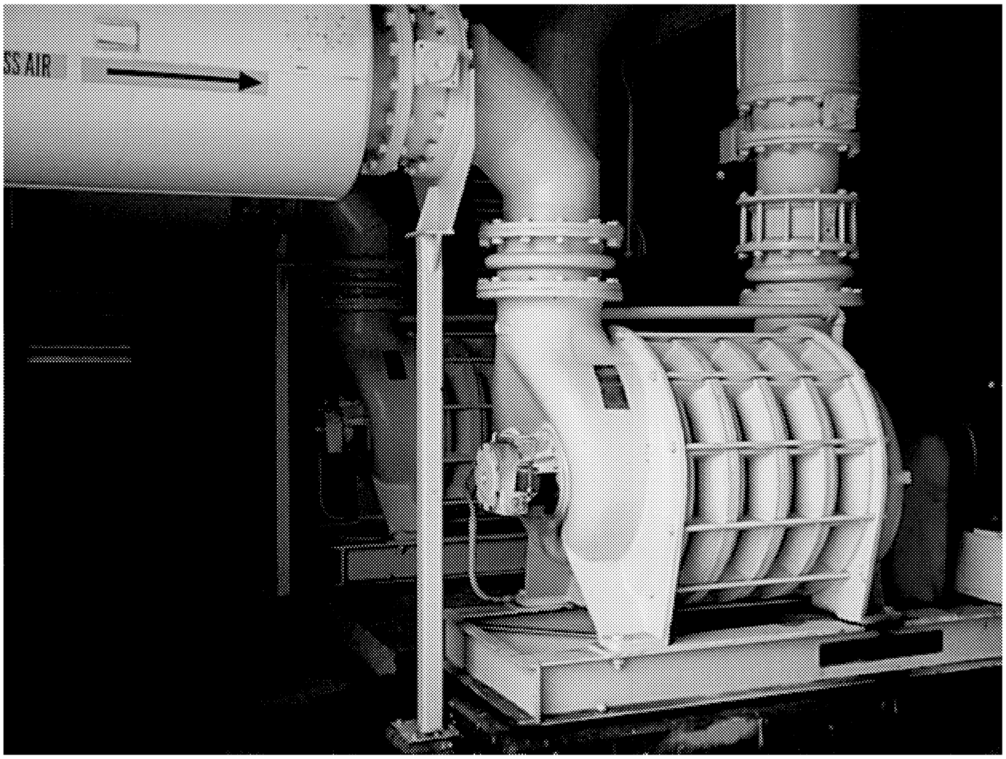
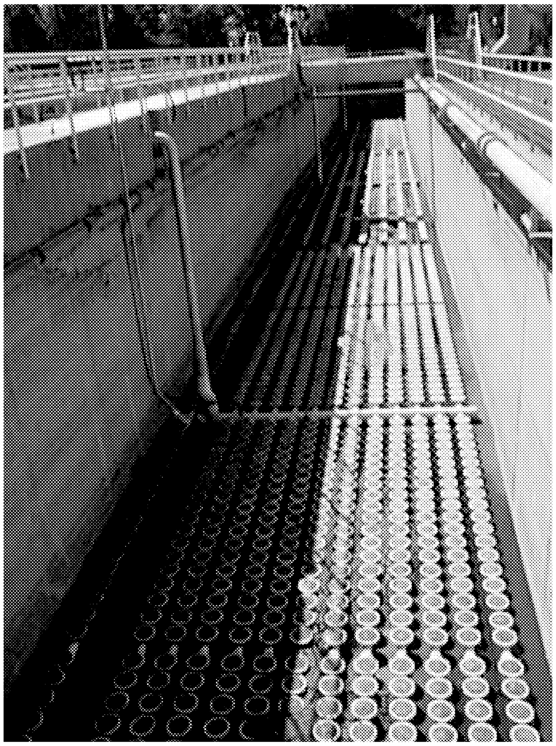
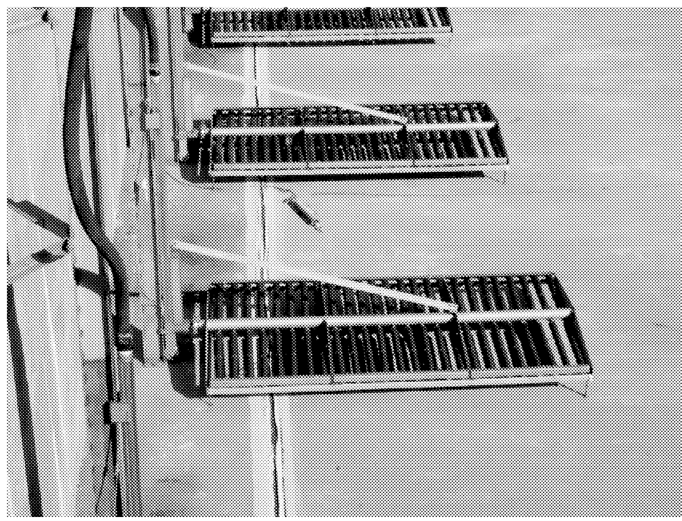


EXHIBIT 5-20

BLOWERS FOR DIFFUSED AERATION





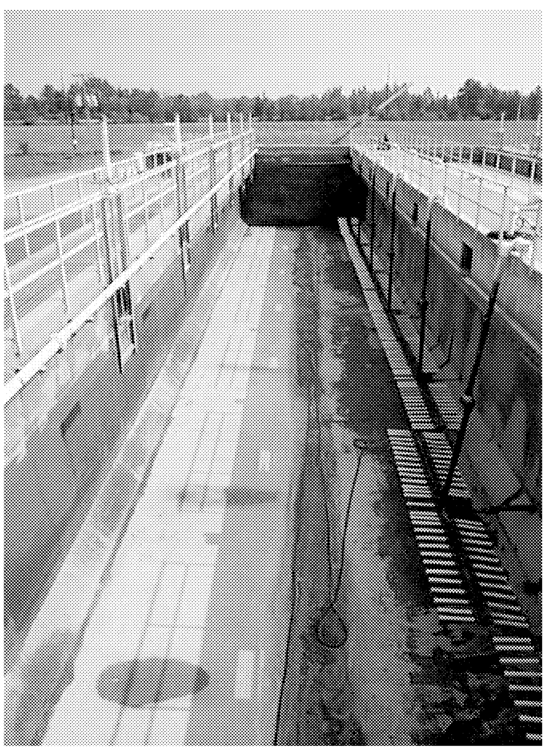
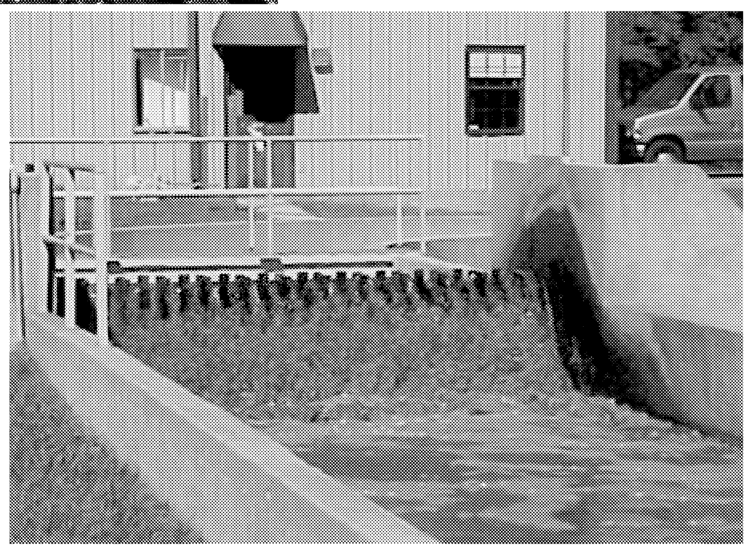


EXHIBIT 5-21

DIFFUSED AERATION SYSTEMS

EXHIBIT 5-22

MECHANICAL AERATION EQUIPMENT



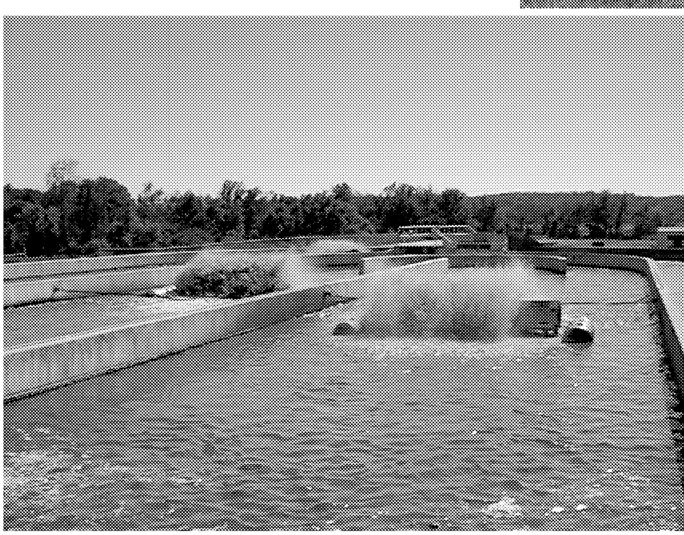
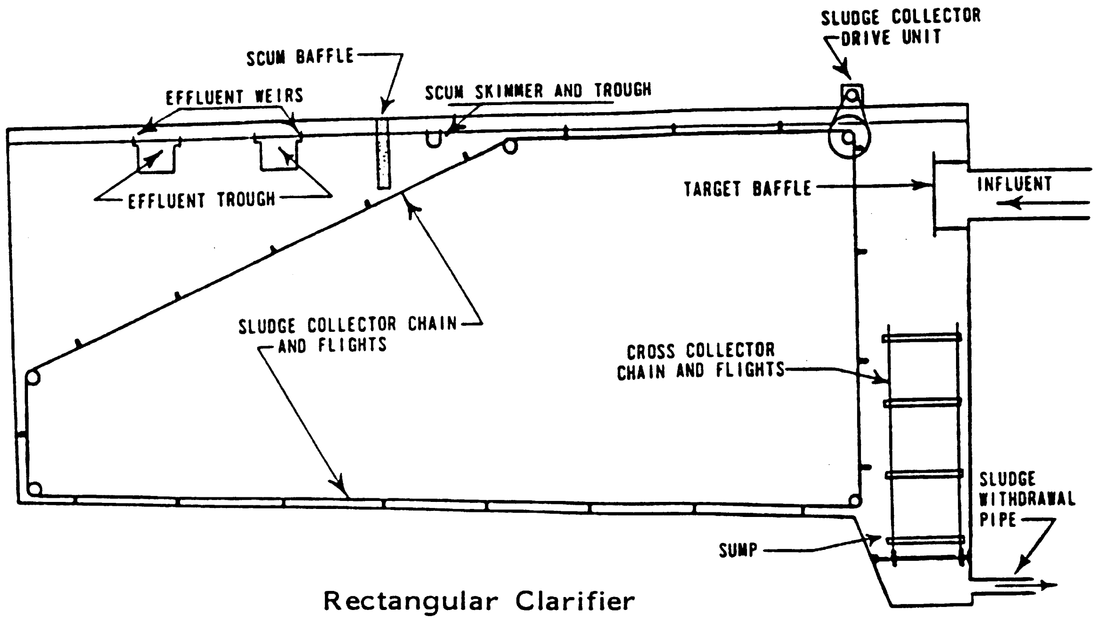
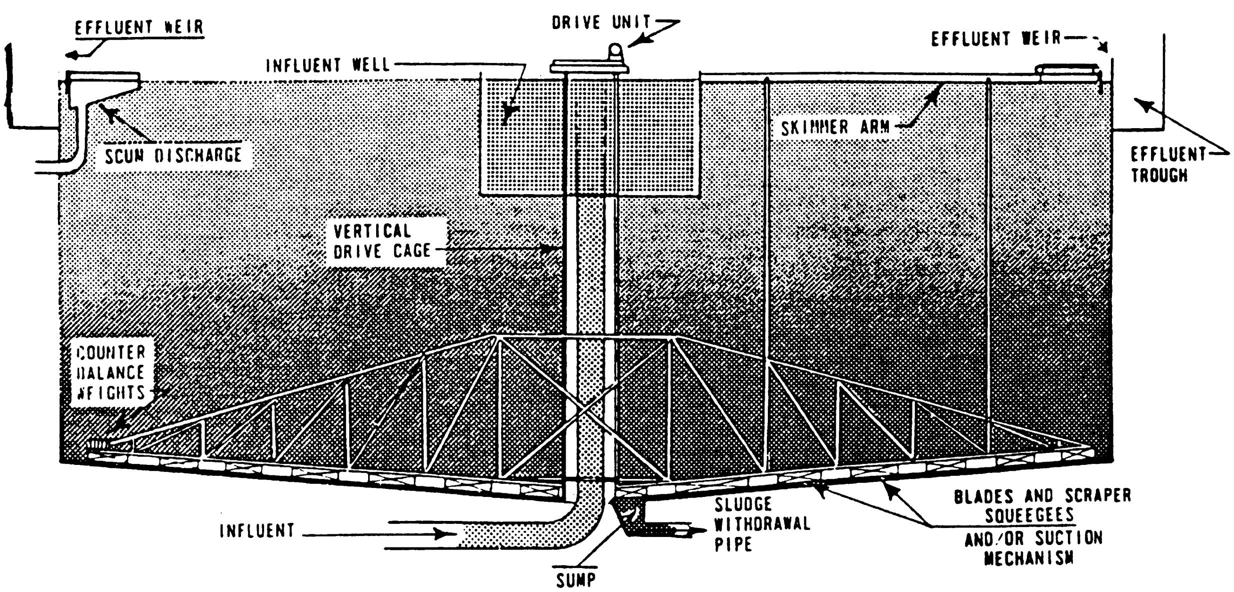


EXHIBIT 5-23

BRUSH AERATION EQUIPMENT



Rectangular Clarifier



Circular Clarifier

EXHIBIT 5-24

CROSS-SECTIONS OF TYPICAL RECTANGULAR AND CIRCULAR CLARIFIERS

Source: “Operation of Wastewater Treatment Plants,” Sacramento State College, Sacramento, California, 1970

Secondary clarifiers can be either rectangular or circular in shape. Exhibit 5-24 depicts the details of both shapes. Flow through rectangular units generally enters at one end, passes a baffle arrangement, and travels the length of the tank to the effluent weirs. Moving collectors scrape the settled sludge from the bottom of the rectangular tank and move it to a hopper located at one end of the tank, from where it is removed. Circular clarifiers normally have the influent entering at the center (center-feed) or around the perimeter (rim-feed). Sludge which settles in a circular clarifier is usually collected in a hopper at the center by rotating scrapers. Clarified effluent usually leaves a clarifier, regardless of its shape, by flowing from the surface over a series of weirs. Exhibit 5-25 shows clarified effluent being discharged from clarifiers at various activated sludge facilities in Mississippi. When the clarifier is properly maintained and when conditions in the aeration tank are such that a "good settling sludge" is produced, the clarified effluent should be low in organic content and suspended matter. There are certain parameters which can be used to evaluate the performance of secondary clarifiers. These include the following:

1. Surface Loading Rate- Surface loading rate is defined as the hydraulic load (gallons per day) applied per unit area (square feet) of clarifier surface. Mathematically, it can be computed as follows:

   $$\text{Surface Loading Rate} = \frac{\text{Flow Applied (GPD)}}{\text{Surface Area (SF)}}$$

   where the flow applied is the total flow or the sum of the raw wastewater flow and any return sludge flow.

   This parameter is also referred to sometimes as the "surface settling rate" or the "surface overflow rate". Typically, it ranges from 600 to 800 GPD/SF.

2. Weir Overflow Rate (WOR) - Weir overflow rate is defined as the hydraulic load (gallons per day) applied per unit length (feet) of effluent weirs. Mathematically, it is computed as follows:

   $$\text{WOR} = \frac{\text{Flow Applied (GPD)}}{\text{Total Length of Effluent Weirs (Feet)}}$$

   where the flow applied is the total flow or the sum of the raw wastewater flow and any return sludge flow.

   For flows less than or equal to one million gallons per day (MGD) the WOR should be less than 10,000 GPD/Ft. For flows in excess of one (1) MGD, the WOR should be less than 15,000 GPD/Ft.

3. Solids Loading Rate - Solids loading is a parameter which is used only for secondary clarifiers in activated sludge processes. It is defined as the amount (Lbs/Day) of mixed liquor suspended solids (MLSS) applied per unit area (Square Feet) of clarifier surface area. Mathematically, it is expressed in units of pounds per day per square foot (Lbs/Day/SF) and can be computed as follows:

   $$\text{Solids Loading Rate} = \frac{\text{MLSS Applied (Lbs/Day)}}{\text{Surface Area (SF)}}$$

   $$= \frac{\text{Average Daily Flow (MGD)} \times \text{MLSS (mg/l)} \times 8.34}{\text{Surface Area (SF)}}$$

   where the flow is the total flow applied or the sum of the raw wastewater flow and any return sludge flow.

   Typically, this parameter should be in the range of 15 to 20 Lbs/Day/SF.

EXHIBIT 5-25

EFFLUENT FROM SECONDARY CLARIFIERS FOLLOWING ACTIVATED SLUDGE FACILITIES

4. Detention Time - Detention time in a clarifier is the amount of time the mixed liquor is allowed to stay in the clarifier for settling. It can be computed by knowing the volume of the clarifier and the flow to the clarifier as follows:

$$\text{Detention Time (Hrs.)} = \frac{\text{Volume (MG) x 24 Hrs./Day}}{\text{Flow (MGD)}}$$

Where the flow is the total flow applied or the sum of the raw wastewater flow and any return sludge flow.

Most secondary clarifiers in activated sludge systems are designed to provide three (3) to five (5) hours detention at average daily flow.

There are two (2) major operational difficulties which are sometimes encountered in secondary clarifiers at activated sludge facilities. The first of these is called "sludge bulking". A bulking sludge is simply a poor settling sludge which is usually produced by the growth of filamentous organisms or by the swelling of bacterial cells through the addition of water. Many factors can lead to the production of bulking sludge conditions and it is frequently very difficult to isolate the major cause. Factors which have been known to contribute to sludge bulking problems include wastewater characteristics (flow fluctuations, pH, temperature, nutrient content, etc.), improper design (air supply, clarifier design, sludge removal limitations, short circuiting, etc.), and improper operation (low dissolved oxygen, organic overload, poor clarifier maintenance). The most successful methods of preventing and controlling sludge bulking include maintaining sufficient dissolved oxygen in aeration tank, maintaining F/M ratio in acceptable range, maintaining acceptable sludge age, and chlorinating return sludge if filamentous organisms are present.

The second major problem is that of "rising sludge". A rising sludge simply rises or floats to the surface after a relatively short settling period. Such a sludge can actually have good settling characteristics. The cause of rising sludge is denitrification in which nitrite (NO_2^-) and nitrate (NO_3^-) are converted to nitrogen gas (N_2). The nitrogen gas is trapped in the sludge mass at the bottom of the clarifier. If enough gas is produced, the sludge mass becomes buoyant and rises to the surface. Small gas bubbles are normally attached to the floating solids. The denitrification is commonly caused by excessive detention in the clarifier, excessive sludge age, or insufficient return/waste sludge rates. The most common response to rising sludge is to increase the rate at which the return/waste sludge is removed from the clarifier.

e. Process Modifications

Over the years, there have been numerous modifications made to the activated sludge process, which have given it greater flexibility in meeting particular wastewater treatment needs. These modifications have not changed the basic characteristics of the process. The four (4) basic components of the process (aeration, sedimentation, return sludge, and waste sludge) remain in tact in each modification. Most of the variations in the process modifications are related to such parameters as the aeration period or sizes of aeration tanks and the manner in which the raw wastewater and return sludge enter the aeration tank.

The most commonly-used activated sludge processes include the following:

1. Conventional Activated Sludge,
2. Extended Aeration,
3. Complete-Mix,
4. Contact Stabilization, and
5. Oxidation Ditch.

Table 5-10 compares the typical characteristics of each of these processes. Exhibits 5-26 thru 5-30 are schematic flow diagrams of each of the processes.

f. Laboratory Controls

Laboratory analyses of collected samples are essential to the proper evaluation and control of the performance of any wastewater treatment facility. This is particularly true for a biological treatment process such as activated sludge. Laboratory tests are used to determine process efficiency; evaluate performance; analyze waste strength and characteristics; evaluate mixed liquor characteristics; and trace, identify, and evaluate operational problems.

The first step in compiling good laboratory test results is the collection of good samples. It is important that a sample be as representative as possible of the conditions which it is intended to reflect. Sampling locations depend upon the layout and design of each particular treatment facility. However, certain basic guidelines for sampling are presented in Exhibit 5-31. Two (2) types of samples can be collected. One is a "grab" sample which consists of a single portion collected at a given time. The other type, which is generally preferred, is a "composite" sample and consists of portions taken at specific intervals and then combined into a single sample.

The most common laboratory analyses and field tests which are typically needed for the proper operation and control of activated sludge processes include the following:

1. Total Suspended Solids (TSS) - This test should be conducted on samples of the influent, mixed liquor, return/waste sludge, and effluent. It is this analysis, when conducted on mixed liquor, that is used to determine the mixed liquor suspended solids (MLSS) which is subsequently used in computing SVI and sludge age.
2. Volatile Suspended Solids (VSS) - This analysis should be conducted on the influent, mixed liquor, and return/waste sludge. It is used to determine the mixed liquor volatile suspended solids (MLVSS) which is used in computing F/M ratio.
3. Dissolved Oxygen (D.O.) - The dissolved oxygen content of the aeration tank and final effluent should be monitored.
4. Sludge Settleability - A 30-minute sludge settleability test conducted on the mixed liquor is indicative of how well the sludge will settle when it is placed in a clarifier. The results of this test are used in determining SVI.
5. 5-Day Biochemical Oxygen Demand (BOD_5) - The BOD_5 analysis should be conducted on the influent and effluent and the results used to determine removal efficiency. Also, the influent results are used to compute F/M ratio.
6. Ammonia Nitrogen - This analysis is typically conducted on the influent and effluent to determine nitrification efficiency.
7. pH - The pH of influent, mixed liquor and effluent should be monitored.

TABLE 5-10

COMPARISON OF CHARACTERISTICS OF ACTIVATED SLUDGE PROCESSES

	PROCESS MODIFICATION				
CHARACTERISTIC	CONVENTIONAL	EXTENDED AERATION	COMPLETE MIX	CONTACT STABILIZATION	OXIDATION DITCH
Primary Clarifier	Usually Provided	Generally None	Optional	Optional	Generally None
Aeration Period (Hours)	6-8	24	3-4	½ - 1 (Contact) 1½ - 3 (Stab.)	15-40
Secondary Clarifier	Always Provided	Always Provided	Always Provided	Always Provided	Always Provided
% Return Sludge	25-50	Up to 100	Up to 100	30-50	Up to 100
Organic Loading (Lbs. BOD/DAY/ 1000 CF)	35-40	12-20	75-100	70	10-15
Sludge Age (Days)	5-7	10-20	3-5	3-7	15-30
F/M Ratio	0.2-0.5	0.05-0.20	0.3-0.6	0.2-0.5	0.05-0.20
BOD_5 Removal (%)	85-90	85	90-95	90	95

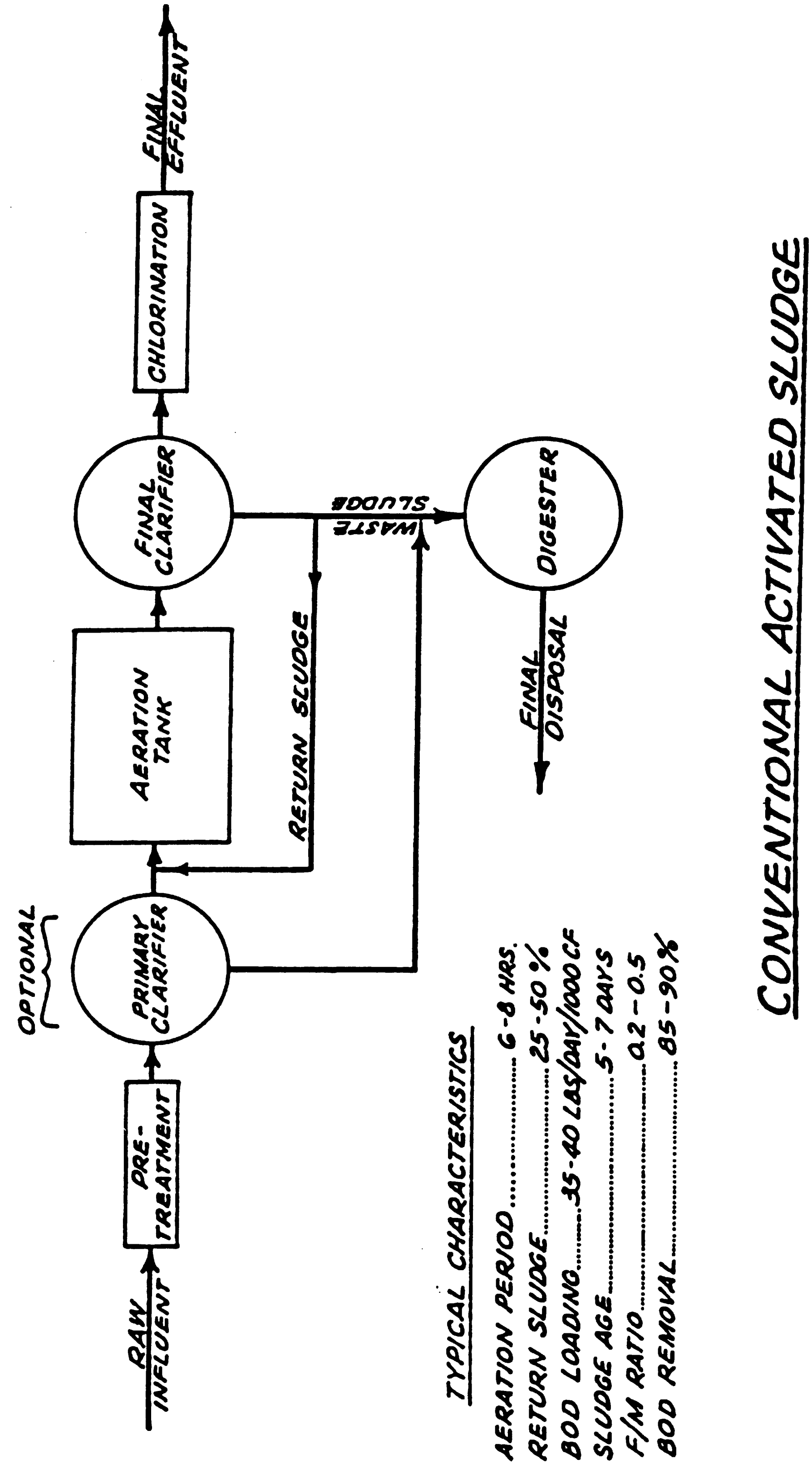
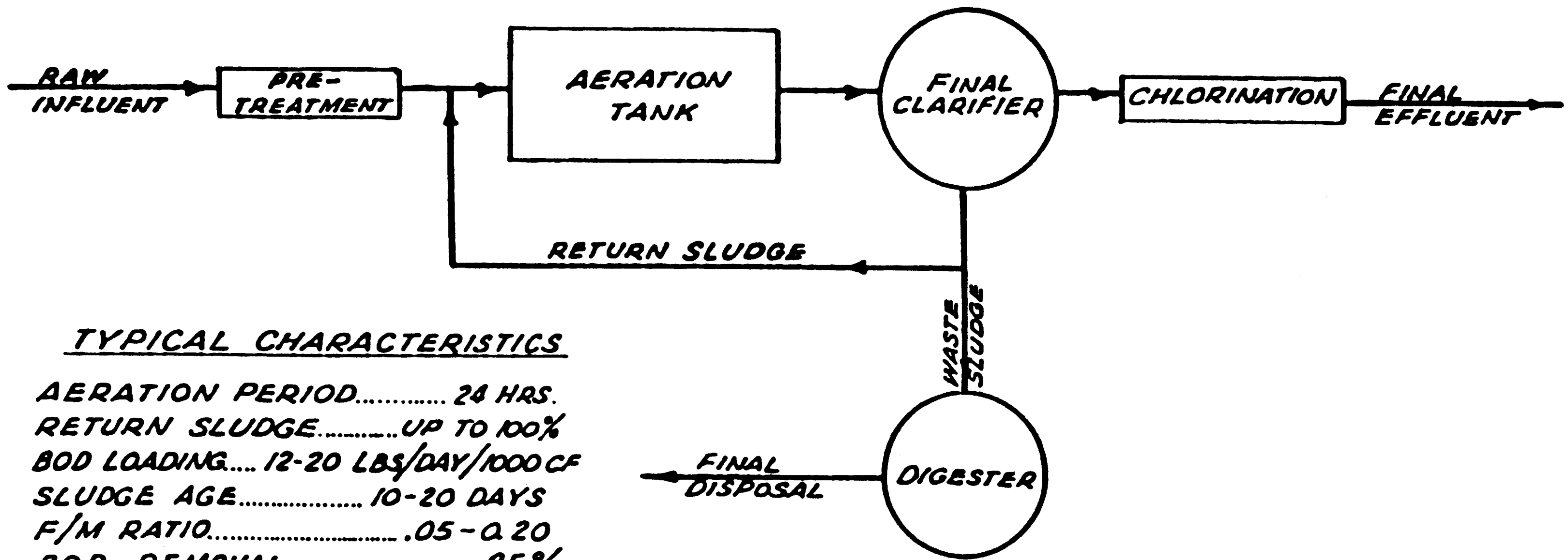

CONVENTIONAL ACTIVATED SLUDGE
RAW INFLUENT
PRE-TREATMENT
OPTIONAL
PRIMARY CLARIFIER
AERATION TANK
RETURN SLUDGE
FINAL CLARIFIER
WASTE SLUDGE
DIGESTER
FINAL DISPOSAL
CHLORINATION
FINAL EFFLUENT
TYPICAL CHARACTERISTICS
AERATION PERIOD .... 6-8 HRS.
RETURN SLUDGE 25-50%
BOD LOADING .... 35-40 LBS/DAY/1000 CF
SLUDGE AGE .... 5-7 DAYS
F/M RATIO 0.2-0.5
BOD REMOVAL 85-90%

EXHIBIT 5-26

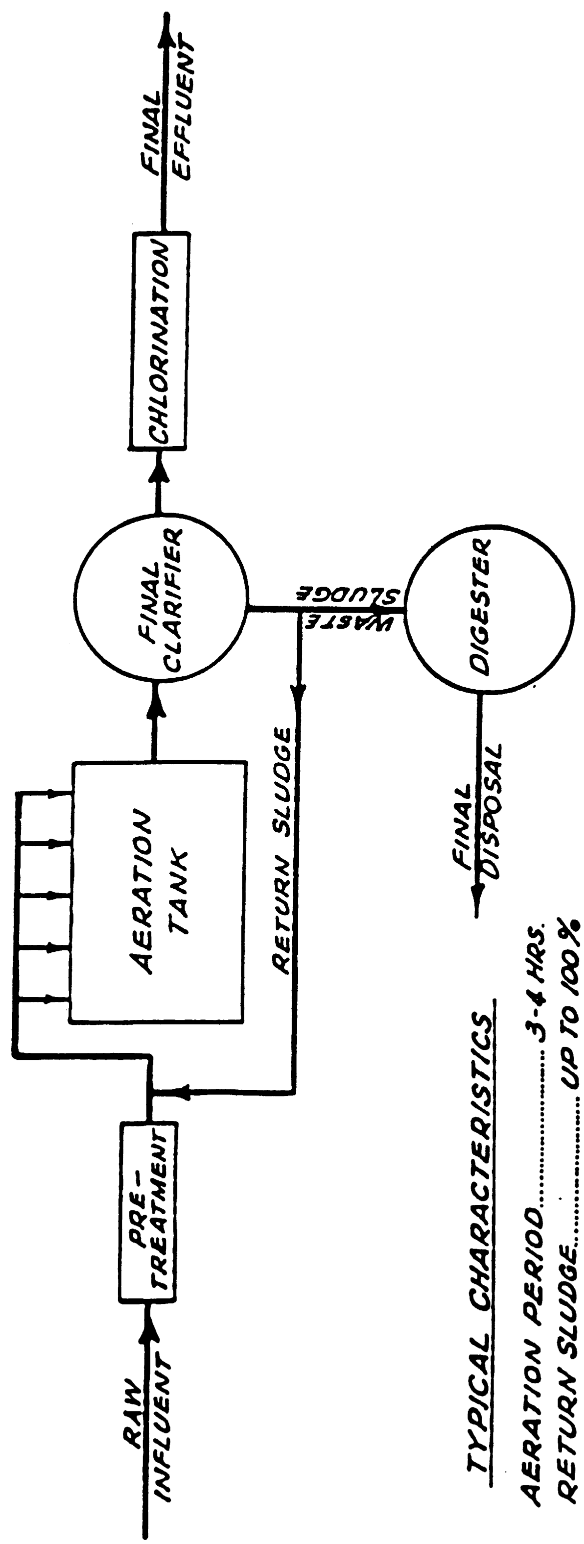


TYPICAL CHARACTERISTICS

AERATION PERIOD............ 24 HRS.
RETURN SLUDGE............UP TO 100%
BOD LOADING..... 12-20 LBS/DAY/1000 CF
SLUDGE AGE.................. 10-20 DAYS
F/M RATIO.......................... .05 - 0.20
BOD REMOVAL.............................85%

EXTENDED AERATION

EXHIBIT 5-27

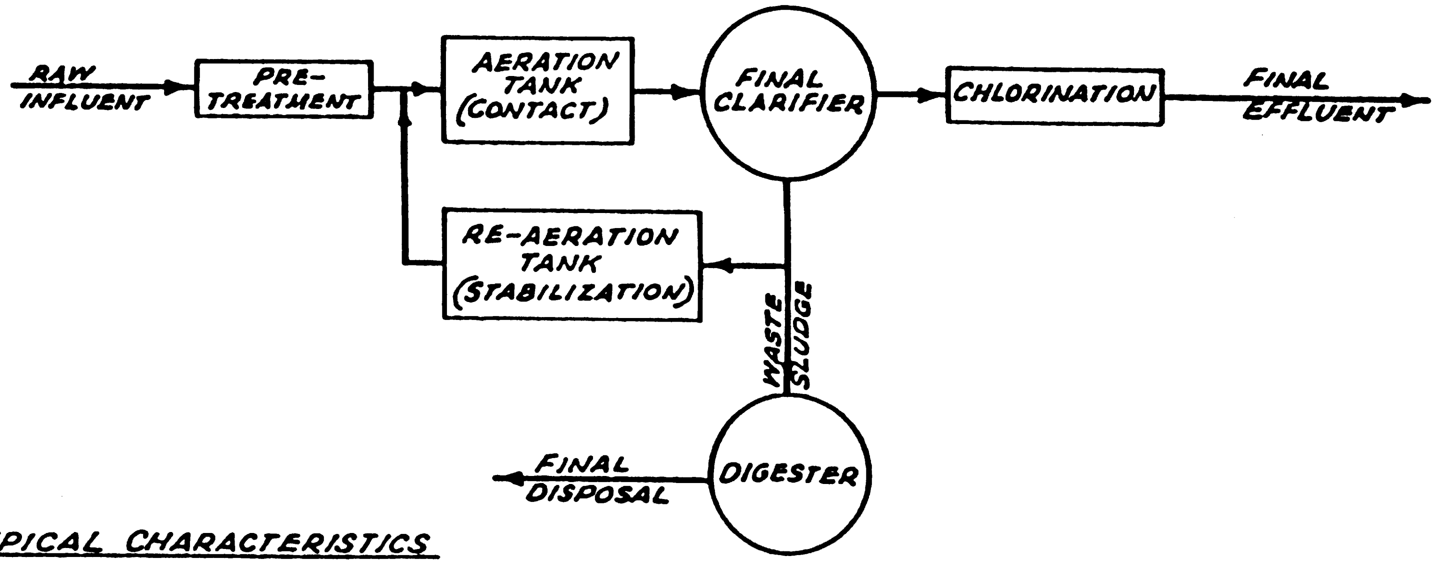


TYPICAL CHARACTERISTICS

AERATION PERIOD.......... 3-4 HRS.
RETURN SLUDGE.......... UP TO 100%
BOD LOADING...... 75-100 LBS/DAY/1000 CF
SLUDGE AGE.......... 3-5 DAYS
F/M RATIO.......... 0.3 - 0.6
BOD REMOVAL.......... 90 - 95%

COMPLETE-MIX ACTIVATED SLUDGE

EXHIBIT 5-28



TYPICAL CHARACTERISTICS

AERATION PERIOD......1/2 - 1 HR. (CONTACT)
1 1/2 - 3 HR. (STABILIZATION)
RETURN SLUDGE......30 - 50 %
BOD LOADING......70 LBS/DAY/1000 CF
SLUDGE AGE......3 - 7 DAYS
F/M RATIO......0.2 - 0.5
BOD REMOVAL......90 %

CONTACT STABILIZATION

EXHIBIT 5-29

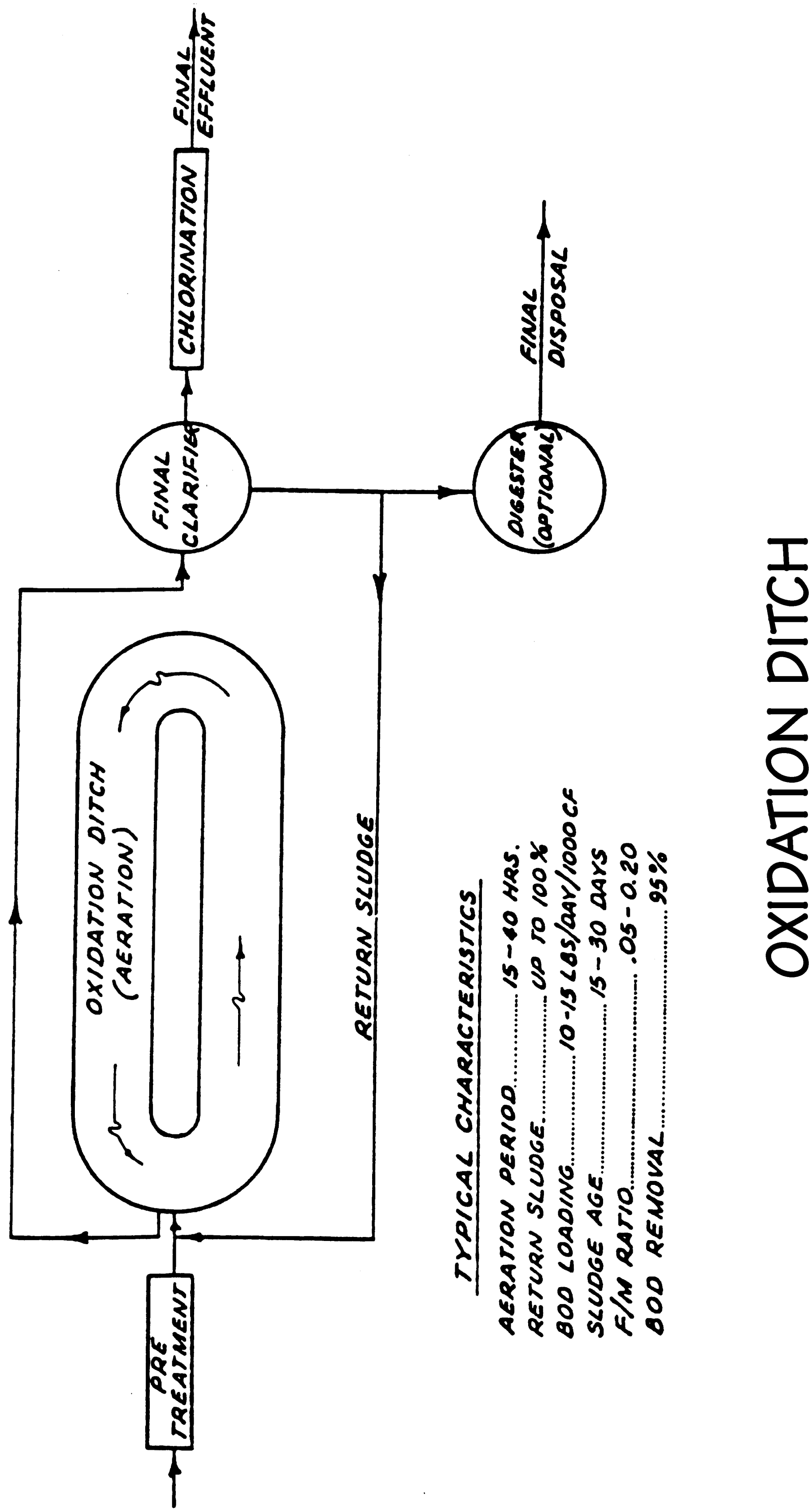
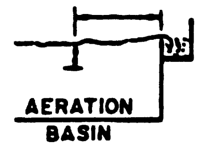

PRE TREATMENT
OXIDATION DITCH (AERATION)
RETURN SLUDGE
FINAL CLARIFIER
CHLORINATION
FINAL EFFLUENT
DIGESTER (OPTIONAL)
FINAL DISPOSAL
TYPICAL CHARACTERISTICS
AERATION PERIOD.......15-40 HRS.
RETURN SLUDGE.......UP TO 100%
BOD LOADING.......10-15 LBS/DAY/1000 CF
SLUDGE AGE.......15-30 DAYS
F/M RATIO.......05-0.20
BOD REMOVAL.......95%
OXIDATION DITCH

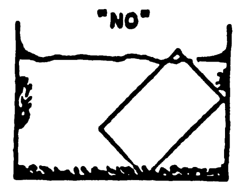
EXHIBIT 5-30

Sampling point should be readily accessible and adequate safety precautions should be observed.

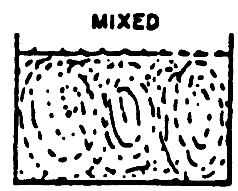
MLSS samples should be collected at a convenient distance from the sides of the aeration basin.



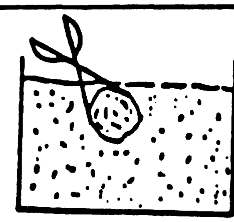
No deposits or materials should be collected from the side walls or the water surface.



Sample must be taken where the wastewater is mixed and of uniform composition.



Large or unusual particles should not be collected with routine samples.



Sample should be delivered and analyzed as soon as possible. Stored samples must be refrigerated at 3 to 4° C.

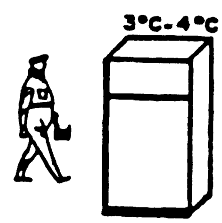


EXHIBIT 5-31

WASTEWATER SAMPLING GUIDELINES

Source: "Process Control Manual for Aerobic Biological Wastewater Treatment Facilities," U.S. EPA, 430/9-77-006, March 1977

8. Temperature - The atmospheric and mixed liquor temperatures should be taken periodically and correlated with BOD removal and nitrification results.
9. Microscopic Examination - Microscopic examination of mixed liquor, clarifier contents, and receiving streams are often utilized to evaluate the various kinds of microorganisms which are present.

g. Common Operational Problems

Inherent with any wastewater treatment process are various operating problems which can produce undesirable situations ranging from nuisance conditions to violation of Federal and State pollution control requirements. It is inevitable that an activated sludge facility will experience occasional operational problems; and it is this inevitability which justifies the need for competent and qualified operating personnel.

Before an operational problem can be solved, it must first be identified. Once it has been identified, further investigation can be made as needed to define specific causes and decide upon corrective measures. Investigation of a problem can range from asimple visual observation to detailed and precise laboratory analyses.

Some of the common operational problems, along with their causes and cures, that are typically encountered at activated sludge facilities are presented in Table 5-11.

5-9 SEQUENCING BATCH REACTORS

A sequencing batch reactor (SBR) is an activated sludge system in which the aeration and clarification processes take place in the same tank. Although a single tank is utilized for both, the biological and physical processes which occur during aeration and settling are identical to those in more common activated sludge systems which utilize separate tanks.

Obviously, the aeration and settling processes in SBR systems do not occur at the same time within a tank. Instead, a “fill and decant” mode of operation is exercised whereby flow enters the tank and is subjected to aeration/mixing for a selected amount of time; and thence the aeration is ceased to allow the solids to settle. This mode of operation utilizes intermittent inflow and outflow instead of continuous flow as normally experienced in conventional systems. Because raw wastewater flow to a treatment facility is typically not intermittent, a sequencing batch reactor system must have either an influent storage tank or at least two (2) SBR tanks in order to accommodate raw flow continuously.

Most sequencing batch reactors utilize five (5) operational steps which are implemented sequentially as follows:

1. Fill - During this step, the major purpose is to add raw wastewater to the SBR tank. The amount of wastewater placed in the tank can be controlled by time or volume.
2. Aerate - The purpose of this sequence is to add oxygen to and provide mixing of the tank contents (mixed liquor) so that the biological stabilization of organic matter can be achieved in a homogeneous manner throughout the tank.
3. Settle - During this step, mixed liquor solids are allowed to settle; thereby providing a clarified supernatant to be discharged as effluent.
4. Decant - The purpose of this sequence is to remove clarified supernatant from the SBR tank.

5. Idle - The purpose of this step is to provide time for one SBR tank to complete its fill cycle before switching to another tank. Idling is not always necessary and can be eliminated depending upon operational objectives and needs. Also, depending on operational objectives, sludge wasting can occur during this sequence as required.

All of the aforementioned operational sequences are time controlled to achieve desired effluent quality and/or other operational objectives.

5-10 GENERAL OPERATION AND MANAGEMENT NEEDS

The successful treatment of wastewater is dependent on two (2) major factors. First, the treatment facility must be properly designed and constructed to achieve the desired level of treatment. Secondly, the treatment facility must be properly operated and managed so that its design capabilities are realized. With regard to the latter factor, the following are matters which must be addressed in providing proper operation and management:

1. Staffing - The quality of operation will normally reflect the qualities of the personnel responsible for operation. It is absolutely essential that a treatment facility be sufficiently staffed with competent and qualified personnel. Personnel should be encouraged, or even required, to regularly participate in short courses, seminars, correspondence courses, and other training activities in order to maintain a high level of operational knowledge and skills. Pay incentives should be available which encourage and reward personnel who successfully participate in training and certification activities. Only certified or licensed personnel should be permitted to fill supervisory and decision-making positions. Job descriptions and experience/educational requirements should be established and enforced for every position.

2. Laboratory Facilities - The proper operation of any wastewater treatment facility is virtually impossible without adequate laboratory results. It is desirable that each treatment facility be equipped with or have access to sufficient equipment and apparatus to conduct those analyses which are pertinent to the particular type treatment process involved. In larger facilities, being equipped with in-house laboratory capabilities is considered a necessity. Smaller facilities may find it more economical and desirable to contract lab services to an outside laboratory. In either event, it is important to recognize that proper operation and management of a wastewater treatment facility can not be achieved without dependable laboratory results.

3. Equipment Maintenance - It is both uneconomical and foolish to neglect equipment and not provide it with proper maintenance. Each item of equipment in a wastewater collection and treatment system has certain procedures for preventive and corrective maintenance recommended by the manufacturer. Proper management of a facility will include a well-planned and routine maintenance schedule for all equipment. When repair of equipment is necessary, adequate tools and work area should be provided for personnel to make repairs.

4. Grounds Maintenance and Housekeeping - A well-operated facility is virtually always one that is neat and clean in appearance. The regular and routine upkeep of grounds and buildings is as much a part of a properly managed facility as equipment maintenance. Neat and well-trimmed grounds such as those shown in Exhibit 5-32 will do much to present a good image to the general public, State and Federal inspectors, and other visitors. Good housekeeping and groundskeeping practices reflect the pride of the operational personnel in their job. Similarly, a lack of good housekeeping and groundskeeping practices will reflect a lack of pride in the facility.

5. Records and Reports - The proper management of any operation is virtually impossible without an organized and well-kept system of records and reports to reflect what the operation is and has been doing. Keeping and filing records is largely a matter of habit and routine. Once the practice of record keeping is begun and established, it becomes a routine matter. The keeping of records and reports should be a routine and regular day to day activity. Chapter 12 of this manual provides a discussion on the types of records that should be maintained.

Table 5-11

COMMON OPERATIONAL PROBLEMS IN ACTIVATED SLUDGE PROCESSES*

Problem	Observations	Probable Cause	Necessary Checks	Remedies
Improper Aeration	1. Boiling action, violent turbulance throughout aeration tank; large air bubbles (½" or greater) apparent.	A. Overaeration	1. Generally, D.O. should be in the range of 1.0 to 2.0 mg/l throughout the tank.	a. Reduce air supply to maintain D.O. in proper range.
	2. Uneven surface aeration pattern; dead spots or inadequate mixing in some areas of tank.	A. Plugged Diffusers	1. Check maintenance records for last cleaning of diffusers.	a. If diffusers have not been cleaned in the last 12 months, do so.
			2. Spot check diffusers in tank for plugging.	b. If several diffusers are plugged, clean all of them in the tank.
		B. Underaeration	1. Check D.O., should be in the range of 1.0 to 2.0 mg/l throughout the tank.	a. Increase air supply to maintain D.O. in proper range.
	3. Excessive air being supplied with no apparent change in organic or hydraulic loading; difficult to maintain adequate D.O. level.	A. Leaks in aeration piping	1. Check air pipes and joint connections; listen for air leakage or soap test flanges and watch for bubbling caused by air leaking.	a. Tighten flange bolts and/or replace flange gaskets.
		B. Plugged diffusers; air discharging from diffuser header blow-off.	1. Check maintenance record for last cleaning of diffusers.	a. If diffusers have not been cleaned in last 12 months, do so.
			2. Spot check diffusers in tank for plugging.	b. If several diffusers are plugged, clean all of them in the tank.
		C. Inadequate oxygen transfer	1. Check aeration system performance; diffused aeration should provide 1,500 to 2,000 Cubic Feet of air per pound of BOD removed; mechanical aeration should provide 1.0 to 1.2 pounds of oxygen per pound of BOD removal.	a. Replace with more efficient diffusers or mechanical aerators. b. Add more diffusers or mechanical aerators.
Foam in Aeration Tank	1. White, thick, billowing or sudsy foam on aeration tank surface.	A. Overloaded aeration tank due to low MLSS.	1. Check BOD loading (Lbs/Day) and MLVSS (Lbs.) In aeration; compute F/M ratio; F/M likely is high.	a. Adjust F/M; usually an increase in return sludge rate is needed to lower F/M.

Table 5-11 (continued)

Problem	Observations	Probable Cause	Necessary Checks	Remedies
Foam in Aeration (cont)			2. Check secondary clarifier effluent for solids carryover; effluent will look cloudy.	b. Maintain sufficient return sludge to minimize solids carryover.
			3. Check D.O. levels in aeration tank.	c. Maintain D.O. between 1.0 and 3.0 mg/l.
		B. Excessive sludge wasting causing low MLSS	1. Check and monitor for any of the following trends: a. Decrease the MLVSS. b. Decrease in sludge age, c. Increase in F/M. d. D.O. levels maintained with less air, and e. Increase in waste sludge rate.	a. Reduce waste sludge rate by not more than 10% per day until process approaches normal control parameters. b. Increase return sludge rate; maintain sludge blanket of 1 to 3 feet in clarifier.
		C. Highly toxic water, colder wastewater temperatures. or severe temperature variations.	1. Collect MLSS sample and test for toxic substances and temperatures.	a. Reestablish new MLSS; waste sludge from process.
			2. Monitor influent for temperature variations.	b. Actively enforce sewer use ordinance.
		D. Hydraulic washout of solids from secondary clarifier.	1. Check detention time in aeration tank and surface overflow rate in final clarifier.	a. If hydraulic loadings exceed design capability, use additional aeration tanks and clarifiers if possible. b. Reduce return sludge rate to maintain higher sludge blanket in clarifier.
		E. Improper distribution of influent and/or return sludge.	1. Check and monitor for significant differences in MLSS concentrations between multiple aeration tanks.	a. MLSS, return sludge and D.O. concentrations should be reasonably consistent between multiple tanks.
			2. Check and monitor influent and return sludge flow rates to each aeration tank.	b. Modify distribution method to maintain equal influent and return sludge flow rates to aeration basins.

Table 5-11 (continued)

Problem	Observations	Probable Cause	Necessary Checks	Remedies
Foam in Aeration (cont)	2. Shiny, dark-tan foam on aeration tank surface.	A. Aeration tank approaching underloaded condition to insufficient sludge wasting (high MLSS).	1. Check and monitor for any of the following trends: a. Increase in MLVSS, b. Increase in sludge age, c. Decrease in F/M, d. D.O. level maintained with increased air, and e. Decrease in sludge wasting.	a. Increase waste sludge rate by not more than 10% per day until process approaches normal control parameters and a modest amount of light tan foam is observed on the aeration tank surface.
	3. Thick, scummy dark tan foam on aeration tank surface.	A. Aeration tank is critically underloaded (MLSS to high)	1. Check and monitor for any of the following trends a. Increase in MLVSS, b. Increase in Sludge Age, c. Decrease in F/M, d. D.O. level maintained with increased air, e. Decrease in sludge wasting, f. Increase in chlorine demand of final effluent, and g. Decrease in pH of mixed liquor.	a. Increase waste sludge rate by not more than 10% per day until process approaches normal control parameters and a modest amount of light-tan foam is observed on the aeration tank surface.
Bulking Sludge	1. Clouds of billowing sludge rising and extending throughout clarifier; MLSS settles slowly and compacts poorly.	A. Improper organic loading or D.O. level.	1. Check and monitor for any of the following trends: a. Decrease of MLVSS, b. Decrease in sludge age, c. Increase in F/M, d. Change in D.O. levels, and e. Sudden SVI increase from normal.	a. Decrease waste sludge rate by not more than 10% per day until process approaches normal parameters. b. Temporarily increase return sludge rate to minimize solids carryover from clarifier; continueuntil normal control parameters are reached. c. Maintain D.O. in aeration greater than 0.5 mg/l, preferably between 1 and 3 mg/l.
		B. Filamentous organisms	1. Conduct microscopic exam of mixed liquor and return sludge; try to identify filamentous organisms.	a. If no filamentous organisms are observed, refer to “Probable Cause A” above.

Table 5-11 (continued)

Problem	Observations	Probable Cause	Necessary Checks	Remedies
Bulking Sludge (cont)			2. If filamentous organisms are identified as fungi, check industries for wastes which may cause problems.	b. Enforce sewer use ordinance to eliminate any industrial wastes which may cause problems.
			3. If filamentous organisms are identified as bacteria, check influent and return sludge flows for massive filamentous organisms.	c. If bacterial filamentous organisms are present, chlorinate influent at 5 to 10 mg/l dosage; chlorinate return sludge at 2 to 3 lbs/day/1000 lbs MLVSS.
		C. Nutrient Deficiency in Wastewater	1. Check nutrient levels in influent; rates should be 100 parts BOD to 5 parts total nitrogen, 1 part phosphorus, and 0.5 part iron.	a. If nutrient levels are inadequate. add anhydrous ammonia, trisodium phosphate, and ferric chloride to influent.
			2. Perform hourly mixed liquor settleability tests.	b. Observe tests for improvement in sludge settling characteristics with addition of nutrients.
		D. Low D.O. in Aeration Tank	1. Check D.O. at various locations in aeration tank.	a. If average D.O. is less than 0.5 mg/l, increase air supply until level increases to between 1 and 3 mg/l throughout the aeration tank.
		E. pH in Aeration Tank is less than 6.5.	1. Monitor influent pH	a. If pH is less than 6.5, conduct industrial survey to identify source; stop or neutralize discharge at source.
			2. Check if process is nitrifying due to warm wastewater temperature or low F/M.	b. If source of pH cannot be identified or stopped, neutralize it by adding soda or lime to the influent.
				c. If nitrification is the cause but is not required, increase waste sludge rate by not more than 10% per day to stop nitrification.
				d. If nitrification is the cause and is required, raise pH by adding soda or lime to the influent.

Table 5-11 (continued)

Problem	Observations	Probable Cause	Necessary Checks	Remedies
Rising Sludge	1. Sludge clumps rising to and dispersing on clarifier surface; bubbles appear on clarifier surface; mixed liquor settles well in settleability test but rises to surface within about 4 hours.	A. Denitrification in clarifier.	1. Check nitrate (NO_3) content in clarifier effluent. 2. Check clarifier loading parameters 3. Check D.O. and temperature levels in the aeration tank. 4. Check return sludge rate and sludge blanket depth in clarifier.	a. Increase waste sludge rate by not more than 10% per day to reduce or eliminate denitrification. b. Maintain waste/return rates to keep process within proper sludge age and F/M. c. Maintain D.O. at minimum level. d. Adjust return sludge rate to maintain sludge blanket of 1 to 3 feet.
		B. Septic Conditions in Clarifier	1. Check D.O. and temperature levels in aeration tank. 2. Check return sludge rate and sludge blanket depth in clarifier. 3. Check aeration system for plugged diffusers and leaks.	a. Increase air supply to maintain D.O. in acceptable range. b. Adjust return sludge rate to maintain a sludge blanket of 1 to 3 feet. c. Clean diffusers and/or repair air leaks as needed.
Solids in Effluent	1. Secondary clarifier effluent is cloudy and contains suspended matter; mixed liquor settles poorly. for solids carryover.	A. Low MLSS in aeration tank	1. Check F/M ratio and MLSS in aeration tank. 2. Check secondary clarifier effluent 3. Check D.O. levels in aeration tank.	a. F/M ratio likely is high; reduce by increasing return sludge rate. b. Maintain D.O. level between 1 and 3 mg/l.
		B. Increase in Organic Loading. 3. Check D.O. level in aeration tank.	1. Conduct microscopic exam of mixed liquor and return sludge; check for presence of protozoa. 2. Check organic loading in aeration tank.	a. If no protozoa are present, possible shock organic load has occurred. b. Reduce waste sludge rate by not more than 10% per day to bring process back to proper parameters; increase return sludge rate to maintain sludge blanket of 1 to 3 feet.

Table 5-11 (continued)

Problem	Observations	Probable Cause	Necessary Checks	Remedies
Solids in Effluent (cont)				c. Adjust air supply to maintain D.O. between 1 and 3 mg/l.
		C. Toxic Shock Loading.	1. Conduct microscopic exam of mixed liquor and return sludge; check for presence of protozoa.	a. If protozoa are inactive, possibility of recent toxic shock load; re-establish new MLSS; waste existing MLSS from process. b. Actively enforce sewer use ordinance to prevent toxic discharges.
		D. Overaeration (causing mixed liquor floc to shear)	1. Conduct microscopic exam of mixed liquor and return sludge; check for dispersed or fragmented floc and presence of active protozoa.	a. Reduce air supply to maintain D.O. in the range of 1 to 3 mg/l.
Pin Floc	1. Fine pinhead size floc accumulated on clarifier surface and discharging over weirs; mixed liquor settles well; sludge is dense at bottom with fine particles of floc suspended in fairly clear supernatant.	A. Aeration tank approaching underloaded conditions (high MLSS) because of old sludge in system.	1. Check and monitor for the following trends: a. Increase in MLVSS, b. Increase in sludge age, c. Decrease in F/M, d. D.O. levels maintained with increasing air supply, e. Decrease in waste sludge rate, and f. Decrease in organic loading.	a. Increase waste sludge rate by not more than 10% per day to bring process back to optimum control parameters for average organic loading.
	2. Small particles of ash-like material floating on clarifier surface.	A. Beginning of Denitrification	1. Stir floating floc on surface of 30-minute settleability test.	a. If floating floc releases bubbles and settles, increase waste sludge rate by not more than 10% per day to reduce or eliminate level of denitrification. b. If floc does not settle after stirring, refer to procedure below for "Probably Cause B".
		B. Excessive grease in mixed liquor.	1. Conduct a oil grease analysis on MLSS. 2. Check oil/grease content in raw wastewater.	a. If grease content exceeds 15% of the MLSS by weight, institute measures to reduce or remove oil/grease from influent.

Source: "Process Control Manual for Aerobic Biological Wastewater Treatment Facilities," U.S. EPA-430/9-77-006

6. Safety - A well managed treatment facility is a safe facility. The safety of all personnel who work at and visit a treatment facility should be a top priority matter. Chapter 13 of this manual addresses specific safety needs and practices.

Historically, the wastewater treatment field and persons employed therein have not been held in as high esteem as their responsibilities merited. However, with the implementation of pollution control regulations and general environmental concern, the "image" of the wastewater field has changed. It is now recognized that a wastewater facility and its personnel are extremely important to the protection of the environment and thegeneral well-being of the public. Wastewater collection and treatment facilities represent a tremendous investment of money and reflect a commitment toward improving the environment. Consequently, providing proper operation and management of such facilities is not only justified but deserved.

EXHIBIT 5-32

WELL-MAINTAINED GROUNDS AND FACILITIES

CHAPTER 6

ADVANCED TREATMENT METHODS

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TABLE OF CONTENTS

ADVANCED TREATMENT METHODS

6-1 DEFINITION OF ADVANCED TREATMENT

The term "advanced treatment" can be defined in various ways. There is no single definition that is universally accepted - except that the term typically implies that some level of treatment beyond conventional secondary processes is involved. A specific definition can vary somewhat depending on whether the application addresses research, design, or operations. Within the scope of design and operation of wastewater treatment facilities in the State of Mississippi and for purposes of this manual, the term refers to some level of treatment beyond those conventional biological treatment methods (lagoons, trickling filters, activated sludge, etc.) that are normally used for BOD and suspended solids removal. Hence, advanced treatment typically implies that removal of some pollutant(s) other than BOD and suspended solids is included in the treatment scheme.

NPDES permits have long required that BOD and suspended solids be reduced to a defined level, or effluent limit, prior to a treated wastewater effluent being discharged to a stream. It is now routine for said permits to also require defined reductions in ammonia nitrogen prior to an effluent being discharged. The need to reduce the levels of nitrate nitrogen and phosphorus in effluent discharges is expected to soon be a common NPDES permit requirement. Thus, for purposes of this manual, the term "advanced treatment" refers to treatment methods for removal of nitrogen and/or phosphorus beyond conventional biological processes that are focused on BOD and suspended solids removal.

6-2 BASIC CONCEPTS OF NITROGEN REMOVAL

a. The Need for Nitrogen Removal

Nitrogen content in treated effluents is important in wastewater treatment because of the effects that nitrogenous materials can have on the environment. Nitrogen exists in many forms and can be changed from one form to another through biological processes in plants and animals. The relationship between the various forms of nitrogen is illustrated in the nitrogen cycle as shown in Exhibit 6-1.

The specific forms of nitrogen which are important in wastewater treatment are: N_2 (Nitrogen Gas), NO_2^- (Nitrite), NO_3^- (Nitrate), NH_3 (Ammonia), NH_4^+ (Ammonium Ion), and Organic Nitrogen. Ammonia (NH_3) and ammonium (NH_4^+) are both commonly referred to as "ammonia nitrogen." These two forms of nitrogen can rapidly change from one to the other depending on pH and temperature. Exhibit 6-2 illustrates the relative distribution of ammonia and the ammonium ion in water.

In raw domestic wastewater, nitrogen exists primarily as organic nitrogen and ammonia nitrogen. A typical distribution would show approximately 40% as organic nitrogen and 60% as ammonia nitrogen. The sum of organic nitrogen and ammonia nitrogen is referred to as "Total Kjeldahl Nitrogen" (TKN). In biological treatment processes, the organic nitrogen is quickly changed to ammonia nitrogen by natural processes. The subsequent removal of ammonia in a treatment process is usually achieved by converting the ammonia to another form of nitrogen. The most common conversion process is nitrification in which ammonia is converted to nitrite and thence to nitrate. Denitrification is a process in which nitrate is subsequently converted to nitrogen gas. The extent and purpose to which nitrification and denitrification are applied are dependent on the level of nitrogen removal required and the specific treatment method(s) used.

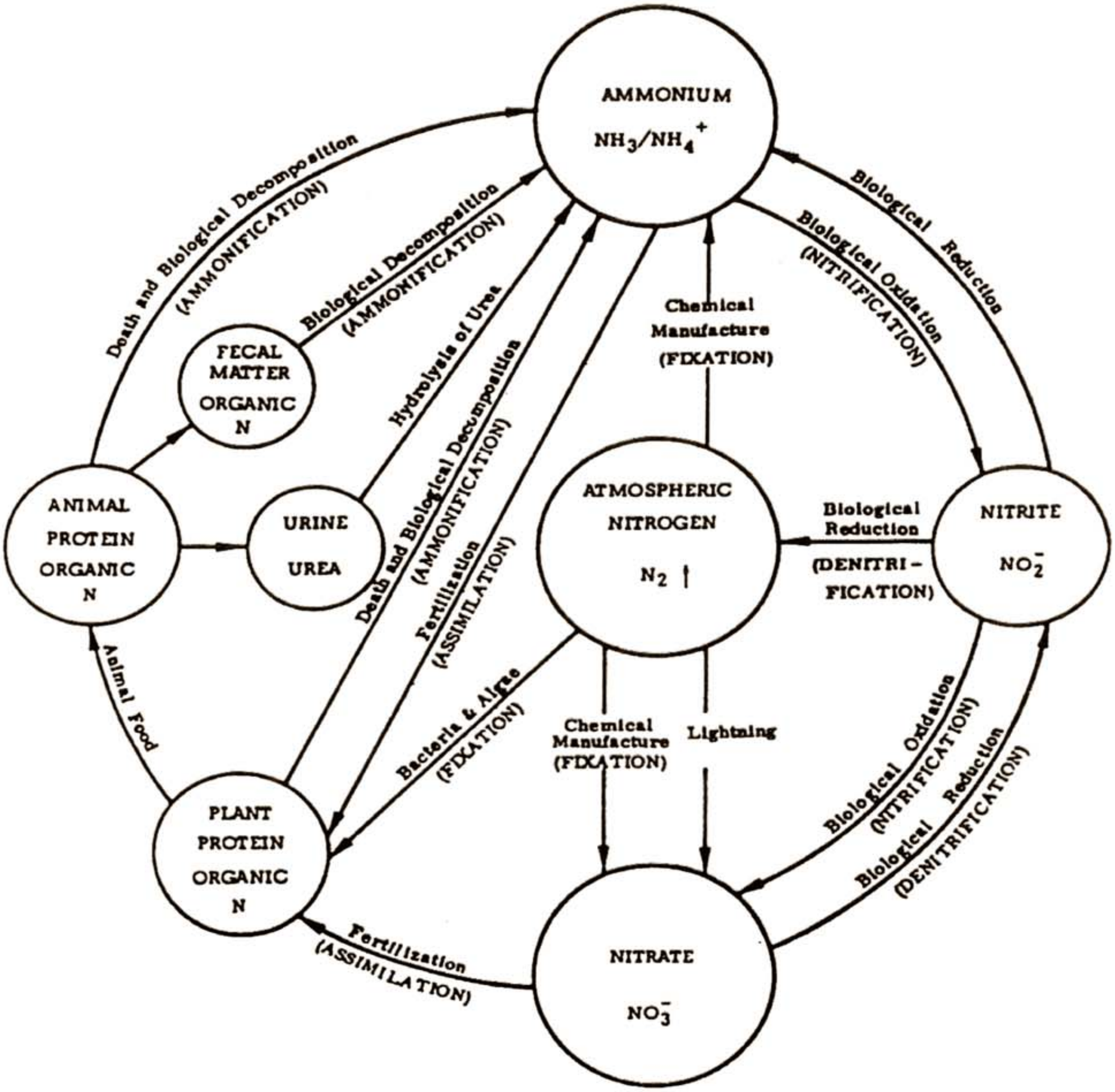


EXHIBIT 6-1

THE NITROGEN CYCLE

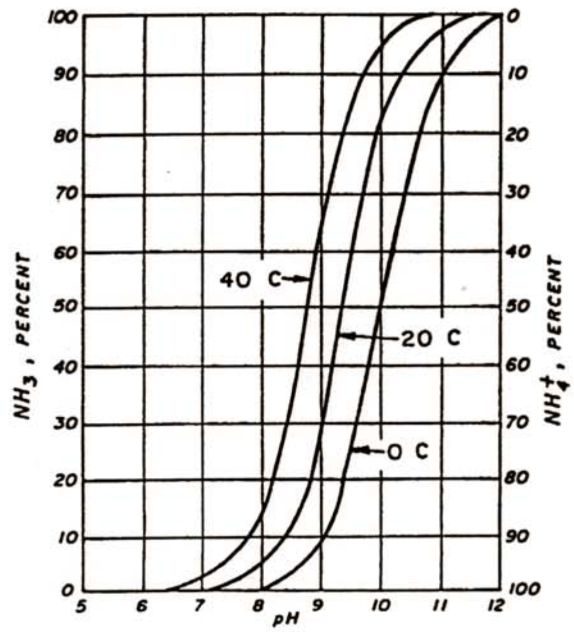
Source: Process Design Manual for Nitrogen Control

U.S. EPA, Technology Transfer

The need for removal of nitrogenous materials in treated wastewater effluents typically focuses on ammonia nitrogen and nitrate. The reasons for needing to limit the amount of these forms of nitrogen in treated effluents vary with the water quality requirements in effect for the receiving stream.

Reasons for removal of ammonia nitrogen from treated effluents can be summarized as follows:

1. Ammonia exerts an oxygen demand on the receiving stream. Thus, if an excessive amount of ammonia is present in an effluent, the oxygen content in the receiving stream can be depleted below that required by water quality standards.
2. Excessive amounts of ammonia can be toxic to biological life in the receiving stream.
3. Ammonia reacts with chlorine to form chloramines which can interfere with disinfection.



DISTRIBUTION OF AMMONIA (NH_3) and AMMONIUM (NH_4^+) IN WATER

EXHIBIT 6-2

Source: Process Design Manual for Nitrogen Control

U.S. EPA, Technology Transfer

Of the three reasons cited above, the first comprises the major need for removal of ammonia nitrogen in treated effluents.

The need for removal of nitrate nitrogen from treated effluents is largely confined to locations where nutrient content is critical for the receiving stream. Nitrate is a nutrient which serves as a fertilizer and the growth of aquatic plants can thrive in its presence. In certain bodies of water, it is necessary to limit the amounts of fertilizing nutrients such as nitrates and phosphates which may be discharged in treated effluents to prevent excessive growths of algae and aquatic plants. Through a process known as eutrophication, such excessive growths result in large masses of algae and nuisance plants that can cause serious harm or even destroy the aesthetic value of a body of water.

b. Biological Nitrogen Removal

i. Overview

Removal of nitrogen from treated wastewater effluents by biological means is typically categorized into the two (2) processes of nitrification and denitrification. Whether either or both of these processes are needed for a particular wastewater treatment application depends on the effluent quality required and/or desired.

Nitrification is a process in which ammonia nitrogen is converted to nitrate nitrogen. This process is achieved biologically by specific bacteria that oxidize ammonia to nitrite and thence oxidize the nitrite to nitrate. Nitrification is applicable where effluent quality demands a reduction in ammonia to a specified level.

Denitrification is a process in which several groups of bacteria convert nitrate to nitrogen gas which is thence released to the atmosphere. This process is applicable where effluent quality demands a reduction in total nitrogen in general and/or nitrate in particular.

ii. Nitrification

Nitrification is an aerobic process in which bacteria convert ammonia nitrogen to nitrate nitrogen. The conversion of ammonia to nitrate is primarily accomplished in a two-step process by nitrifying bacteria named Nitrosomonas and Nitrobacter. These two types of bacteria are both autotrophic and they each have a specific role in the two-step process. Nitrosomonas converts ammonia to nitrite in the first step and Nitrobacter subsequently converts the nitrite to nitrate in the second step.

Proper conditions must exist for the nitrification process to be enacted efficiently. Factors which constitute said proper conditions and thus influence the rate at which ammonia is converted to nitrate are as follows:

1. Carbonaceous Organic Matter – The nitrifying bacteria convert the ammonia to nitrite and nitrate much more efficiently when there is little carbonaceous organic matter (BOD_5) present. Typically treatment systems are designed to provide long aeration periods or separate compartments to significantly reduce the organic matter prior to achieving nitrification. The ratio of BOD_5 to Total Kjeldahl Nitrogen (TKN) can be used to monitor the relative amounts of organic matter present in a nitrification system. More nitrification can be achieved with a lower ratio of BOD_5 to TKN. It is desirable to have a BOD_5/TKN Ratio of less than 3.0.

2. Dissolved Oxygen – A minimum dissolved oxygen content of 2.0 mg/l is typically needed for biological nitrification. An oxygen demand of 4.57 parts of oxygen per part of ammonia to be oxidized is exerted by Nitrosomonas and Nitrobacter bacteria in the nitrifying process.

3. Alkalinity – Alkalinity is destroyed in the nitrification process and carbon dioxide is produced. It can be assumed that 7.14 mg of alkalinity is destroyed in the nitrification process per mg of ammonia oxidized. This destruction of alkalinity is important because it can lower pH significantly due to the carbon dioxide produced. If the natural alkalinity in the wastewater is sufficient to leave enough alkalinity after the nitrification process, the pH reduction might not be significant. If however, there is insufficient natural alkalinity to withstand the nitrification, the pH reduction can be detrimental by significantly reducing nitrifying rates.

4. pH – The pH of the mixed liquor being nitrified should be at least 7.2, with 8.4 being an optimum value. It is often necessary to have chemical feed systems to raise the pH to an optimum value for efficient nitrification.

5. Temperature – Nitrifying bacteria perform more efficiently at temperatures above 10 °C. Greater nitrification efficiencies are achieved in warmer weather than colder weather.

6. Plug Flow Conditions – The term “plug flow” is intended to mean maximizing detention time in the aeration zones by creating flow routes that utilize as much of the volume in aeration zones as practical. It is common to enhance plug flow conditions in many treatment systems by installing baffles or dividers in aeration zones to assure that detention times are maximized. Because of their long ditch-like configurations, oxidation ditches most nearly provide natural plug-flow conditions. By providing plug-flow conditions, thereby maximizing detention times, the growth of nitrifying bacteria is enhanced.

7. Sludge Age/Mean Cell Residence Time – The degree of nitrification increases as the sludge age (or mean cell residence time) increases. As a general rule, a minimum sludge age of ten (10) to twenty (20) days is needed for significant nitrification. Twenty (20) to thirty (30) days is an optimum range.

8. Toxicity – Nitrifying bacteria are highly susceptible to toxic materials – much more so than bacteria which stabilize carbonaceous organic matter (BOD_5). It is necessary that stringent controls be placed on substances which enter a biological nitrification system.

iii. Denitrification

As previously stated, denitrification is normally utilized in wastewater treatment when the desired effluent quality calls for a reduction in total nitrogen in general and/or nitrate in particular. The process is often applied following nitrification in which ammonia has been converted to nitrate. In the denitrification process, nitrate is converted to gaseous forms of nitrogen which are released to the atmosphere. The primary gas produced is nitrogen gas (N_2); but small quantities of nitrous oxide (N_2O) or nitric oxide (NO) can also be produced. By changing the nitrate to nitrogen gas, denitrification changes what can be an objectionable form of nitrogen (nitrate) to one (nitrogen gas) which has no significant effect.

Unlike nitrification which is achieved by two (2) specific bacteria (Nitrosomonas and Nitrobacter), denitrification can be accomplished by several groups of bacteria that include Pseudomonas, Micrococcus, Archromobacter, and Bacillus; all of which are heterotrophic and occur naturally in domestic wastewaters. These bacteria convert nitrates to nitrogen gas via a process known as "nitrate dissimilation" in which the chemically-bound oxygen in nitrate replaces molecular dissolved oxygen (as found in aerobic processes) in the respiratory processes of the bacteria. More specifically, the bacteria breakdown the nitrate molecule to get the oxygen needed for their metabolic functions. This process of breaking down of the nitrate molecule takes place in two (2) steps and occurs in an anoxic environment. Anoxic conditions are deficient in dissolved molecular oxygen but contain chemically-bound oxygen such as found in nitrate. Denitrification is commonly categorized as an anaerobic process because of the lack of dissolved molecular oxygen. However, it is more accurate to characterize it as an anoxic process because of the bacteria's ability to use chemically-bound oxygen in nitrate to facilitate their respiratory processes.

Denitrification, through nitrate dissimilation, is a two-step process. In the first step, nitrate is converted to nitrite by the denitrifying bacteria. In the second step, the bacteria convert the nitrite to nitrogen gas. These two (2) steps are somewhat opposite of the two (2) steps in nitrification where ammonia is converted to nitrite and thence to nitrate. In addition to the two-step dissimilation process, denitrifying bacteria are also capable of converting nitrate to ammonia through a process known as assimilation. The bacteria subsequently use the ammonia for a nitrogen source in their metabolic processes. If sufficient ammonia is already present, assimilation of nitrate to ammonia does not occur.

As with nitrification, there are certain conditions which are pertinent to the rate at which denitrification occurs. Such conditions include the following:

1. Anoxic Conditions – In order for denitrification to occur, anoxic conditions must exist. As previously stated, anoxic conditions are deficient in dissolved molecular oxygen but contain chemically-bound oxygen such as found in nitrate. The dissimilation process of breaking down the nitrate molecule to make its chemically-bound oxygen available requires both an electron donor and an electron acceptor. Nitrate gains (accepts) electrons and is reduced to nitrogen gas and a carbon source looses (donates) electrons and is oxidized to carbon dioxide. The anoxic conditions simply ensure that nitrate will serve as an "electron acceptor" in the dissimilation process instead of oxygen.

2. Carbonaceous Organic Matter – In order for denitrification to occur through the dissimilation process, it is necessary that a source of carbon (organic matter) be provided. While numerous sources are available, methanol is usually the preferred choice. Glucose is an example of an alternative source; but economics generally support methanol as the most common choice. The ratio of the amount of methanol required to the amount of nitrate to be denitrified is referred to as the M/N ratio. As a general rule, at least 2.5 to 3.0 pounds of methanol are required per pound of nitrate removed. An M/N ratio of at least 3.0 is typically sufficient to produce complete denitrification.

3. Alkalinity and pH – Denitrification, through the dissimilation process, results in bicarbonate alkalinity being increased and carbon dioxide being reduced. In the strictest theoretical sense, 3.57 parts of alkalinity (as $CaCO_3$) are produced per part of nitrate denitrified. However, as a general rule, it can be assumed that approximately 3 parts of alkalinity should be produced per part of nitrate reduced to nitrogen gas. The reduction in carbon dioxide results in an increase in pH. This increase in alkalinity and raised pH produced by denitrification are opposite of the effects produced by nitrification where alkalinity is destroyed and pH is lowered. Thus, it can be said that denitrification, to some extent, reverses the effects of nitrification with regard to alkalinity and pH. As a general rule, the alkalinity produced by denitrification replaces only approximately one-half of the alkalinity destroyed by nitrification.

c. Chemical and Physical Nitrogen Removal

While the removal of nitrogen from wastewater effluent by biological means is most common, there are also chemical and physical processes for achieving similar results. Chemical processes include breakpoint chlorination and selective ion exchange, both of which are discussed later in this chapter. In breakpoint chlorination, ammonia nitrogen can be oxidized to nitrogen gas by adding chlorine in sufficient quantities to produce the necessary chemical reactions. In selective ion exchange, ammonium ions can be removed by passing the wastewater through a zeolite media in which chemical reactions cause said ions to be attached to the media.

Though not commonly used in the treatment of municipal or domestic wastewaters, air stripping is a physical process whereby ammonia can be removed from treated effluents. This process is discussed later in this chapter. The process is a very simple one in which air-water contact is used to remove ammonia from the wastewater. As the wastewater falls through a tower in which air is forced upward, the ammonia is stripped and discharged to the atmosphere.

6-3 ADVANCED TREATMENT METHODS FOR NITROGEN REMOVAL

a. Suspended-Growth Biological Processes

i. Oxidation Ditch

An oxidation ditch is a modification of the activated sludge process that utilizes a long aeration period. The basic characteristics of this process have been presented earlier in Chapter 5 in Table 5-4 and Exhibit 5-15. Typical oxidation ditches consist of a "racetrack" design that uses long channels with looped or oval configurations. Because of the long aeration period associated with this process, it is easily adaptable for both nitrification and denitrification. The process is more common for applications where nitrification is needed because the lengthy aeration period is highly suitable to producing a long sludge age or mean cell residence time which subsequently allows nitrifying bacteria sufficient time to convert the ammonia to nitrite and thence to nitrate. When used solely for nitrification and when

EXHIBIT 6-3

OXIDATION DITCH

properly designed and operated for such purpose, an oxidation ditch is very capable of consistently producing an effluent containing less than 2 mg/l of ammonia.

If properly designed and operated, an oxidation ditch can also be adapted for denitrification by use of anoxic zones within the ditch that will allow bacteria to convert nitrate to nitrogen gas. An anoxic zone is an oxygen-deficient environment in which dissolved molecular oxygen levels are low but levels of chemically-bound oxygen such as found in nitrate (NO_3^-) are present. The dissolved oxygen content in an oxidation ditch is highest at the point of aeration and thence decreases as the contents move around the ditch. The anoxic zones occur at a point just upstream from the point of aeration where the dissolved oxygen concentration is lowest. In the absence of dissolved molecular oxygen in this anoxic environment, anaerobic bacteria convert the nitrate to nitrogen gas. In order for an oxidation ditch to function as a denitrification process, it must be designed for such by including the anoxic zones and providing means of controlling both mixing and aeration to allow flexibility in maintaining dissolved oxygen levels and mixed liquor concentrations. In a well designed and operated system, an oxidation ditch can typically achieve at least 90% removal of total (ammonia and nitrate) nitrogen. Exhibit 6-3 on page 6-8 is a photo of an oxidation ditch facility

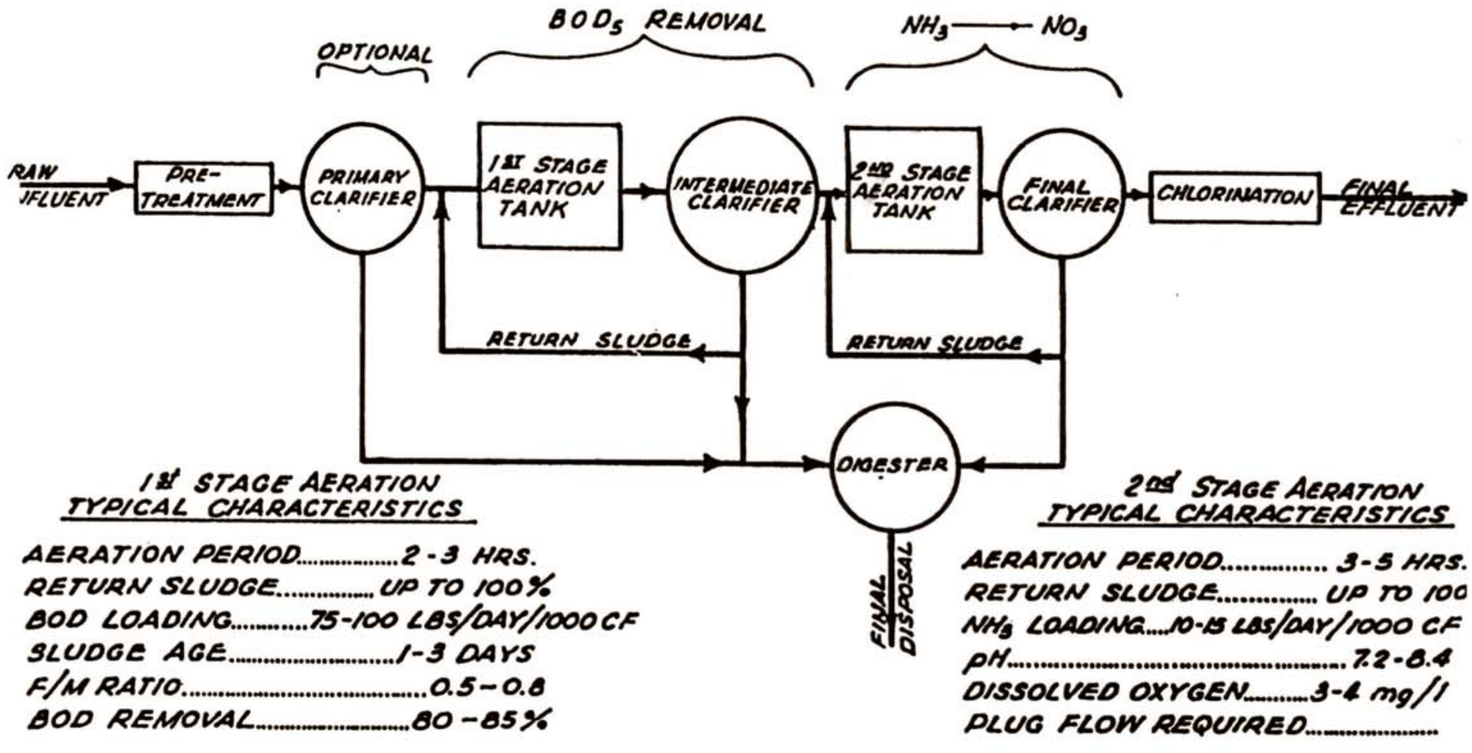
ii. 2-Stage Nitrification

The 2-stage biological nitrification process is a two-sludge system that is typically used when ammonia removal is the focus of advanced treatment. The process is also used ahead of biological denitrification systems where nitrate removal is required. The first stage of the 2-stage process is typically a high-rate activated sludge process which is designed to achieve at least 75% to 85% removal of the carbonaceous BOD_5. By achieving this level of BOD_5 reduction in the first stage, conditions can be developed in the second stage to enhance nitrification.

It is in the second stage that nitrification of the ammonia to nitrate primarily occurs. Nitrification is achieved in a two-step process by the biological activities of two specific groups of bacteria known as Nitrosomonas and Nitrobacter. Nitrosomonas bacteria are involved in the oxidation of ammonia to nitrite. Nitrobacter bacteria thence convert the nitrite to nitrate. These two bacteria do not function effectively to any appreciable degree until the carbonaceous matter (BOD_5) has been significantly reduced in the first stage. The advantage that a 2-stage system offers over other biological nitrification systems such as an oxidation ditch is that two separate aeration chambers are provided. In an oxidation ditch, removal of both BOD_5 and ammonia are achieved in the same aeration chamber. Providing separate systems for BOD_5 and ammonia removal makes the 2-stage system a more efficient method of advanced treatment than an oxidation ditch simply because conditions in each stage can be controlled as needed. In a well designed and properly operated 2-stage system, ammonia effluent concentrations of 1 mg/l can be achieved. Exhibit 6-4 illustrates a typical 2-stage nitrification system.

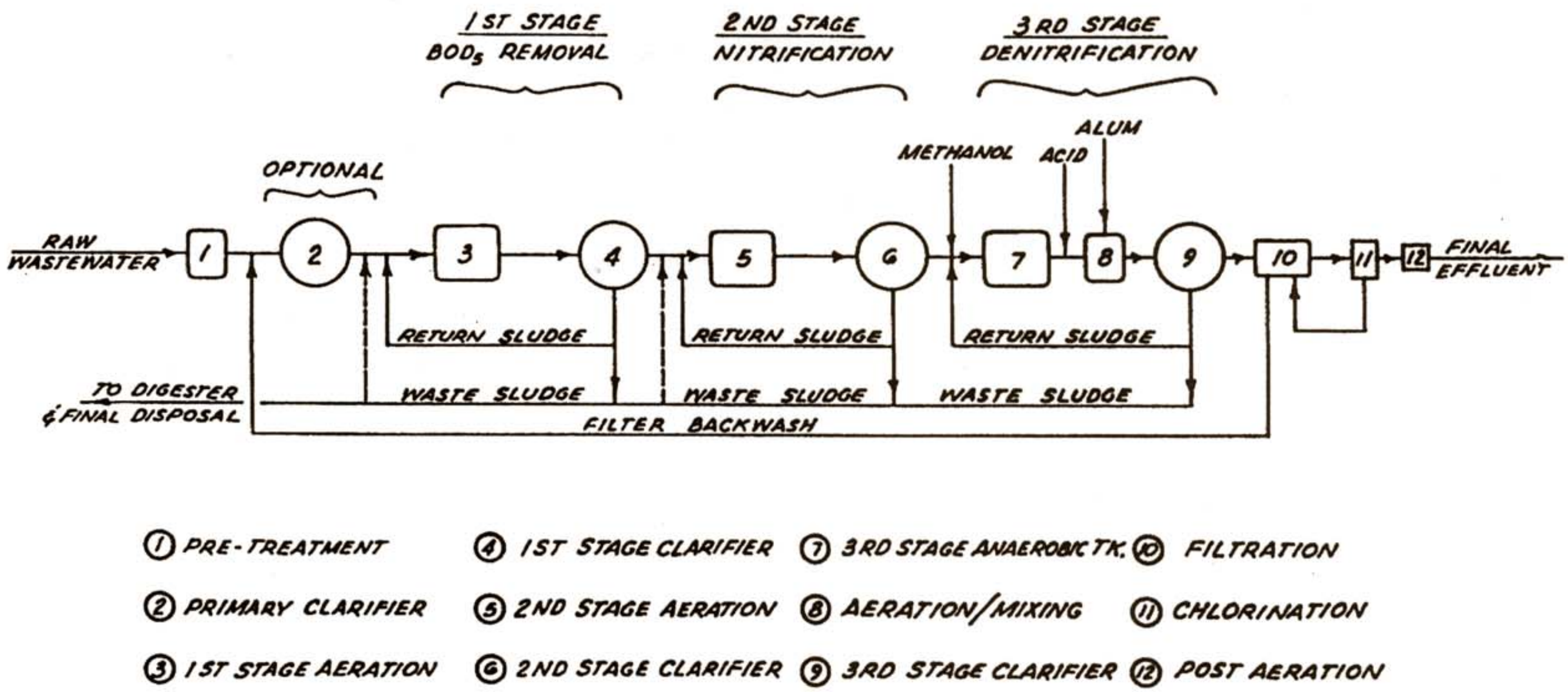
iii. 3-Stage Denitrification

In locations where the nutrient content of a treated effluent is a critical concern, it is often necessary to remove nitrates and phosphates prior to discharge. Removal of phosphates is discussed separately hereinafter. Removal of nitrate can be effectively achieved with a 3-stage denitrification process which is a 3-sludge system in which the first two stages address removal of BOD_5 and conversion of ammonia to nitrate respectively. The third stage achieves denitrification - the conversion of nitrate to nitrogen gas. Exhibit 6-5 depicts the basic components of a typical 3-stage system.



TWO-STAGE BIOLOGICAL NITRIFICATION

EXHIBIT 6-4



3-SLUDGE SYSTEM FOR NITRIFICATION & DENITRIFICATION

EXHIBIT 6-5

In the third stage, denitrification is achieved under anoxic conditions. The heterotrophic bacteria which cause the conversion of nitrate to nitrogen gas require a source of carbonaceous (organic) matter as a food source. Methanol is commonly fed to the contents of the third stage to satisfy this need. Care must be exercised in controlling the methanol feed rate. If too little methanol is fed, the anaerobic bacteria will be unable to achieve the desired results; whereas if too much methanol is fed, an organic (BOD) load will be added to the treated effluent. It is common for the effluent from the denitrification stage to undergo pH adjustment and to be dosed with a chemical coagulant to improve settling.

iv. Ludzack-Ettinger Process

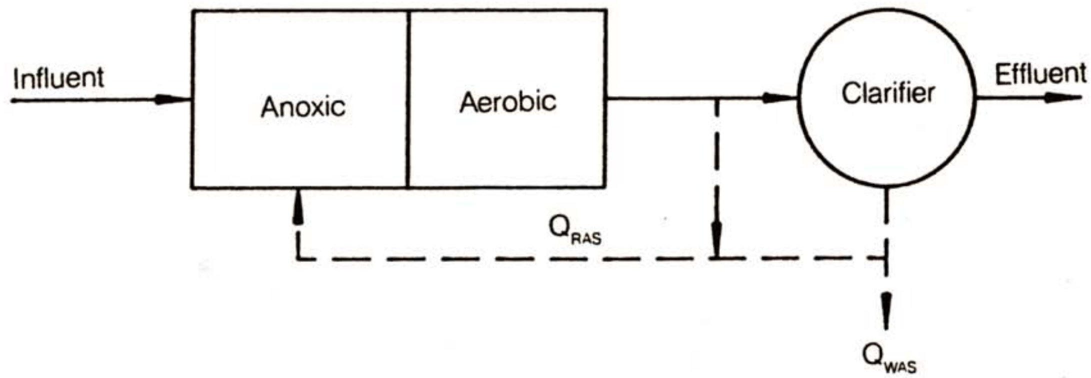
The Ludzack-Ettinger process is a single-sludge pre-denitrification process which uses an anoxic zone ahead of an activated sludge system. The process is used for total nitrogen removal and its efficiency is largely dependent on the rate at which return activated sludge is recycled. Total nitrogen removal rates of 85% are typical in a well designed and properly operated system. In general, the process is used for nitrification and partial denitrification.

A modification of the process which incorporates an internal recycle of activated sludge mixed liquor to the anoxic zone has been used successfully to increase denitrification and overall nitrogen removal. This increase in denitrification is because the internal recycled mixed liquor provides nitrate as an oxygen source while raw wastewater provides a source of readily biodegradable organic matter.

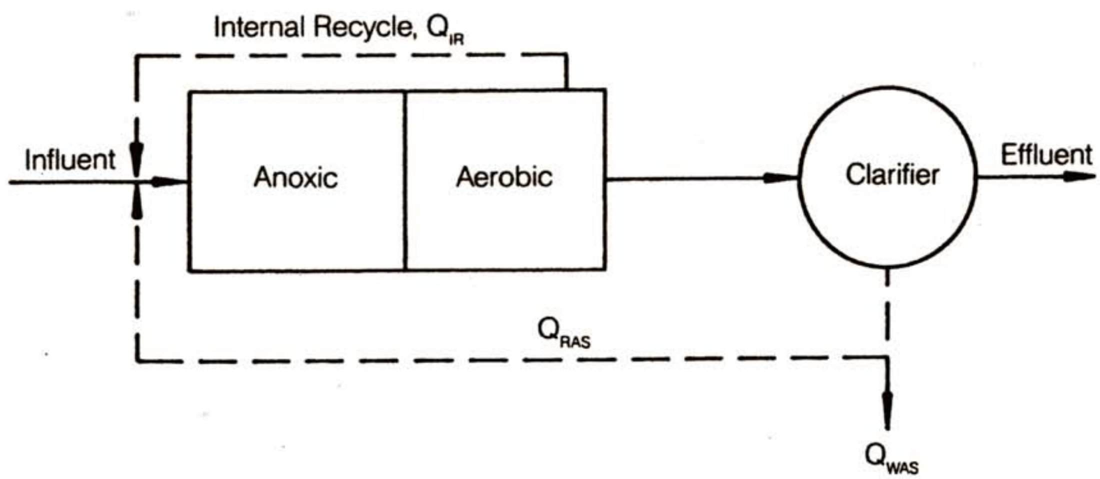
Exhibit 6-6 is a schematic flow diagram which illustrates the basic components of both the Ludzack-Ettinger and Modified Ludzack-Ettinger processes.

v. Bardenpho™ Process

The Bardenpho™ process is a single-sludge system comprised of four alternating anoxic and aerobic zones in series. The first and third zones are anoxic while the second and fourth zones are aerobic. Mixed liquor is recycled from the first aerobic zone to the first anoxic zone at a rate of four to six times the influent flow rate. Return activated sludge is also recycled from the clarifier back to the first anoxic zone. This process is designed to achieve more total nitrogen removal than is possible with two-sludge or three-sludge systems. Effluent concentrations of 2 to 4 mg/l of total nitrogen is possible with this system. As discussed hereinafter, this process can be modified to achieve phosphorus removal with the addition of an anaerobic zone. Exhibit 6-7 illustrates the components of the basic Bardenpho™ process as well as the modified version.



Ludzack-Ettinger Process for Nitrogen Removal



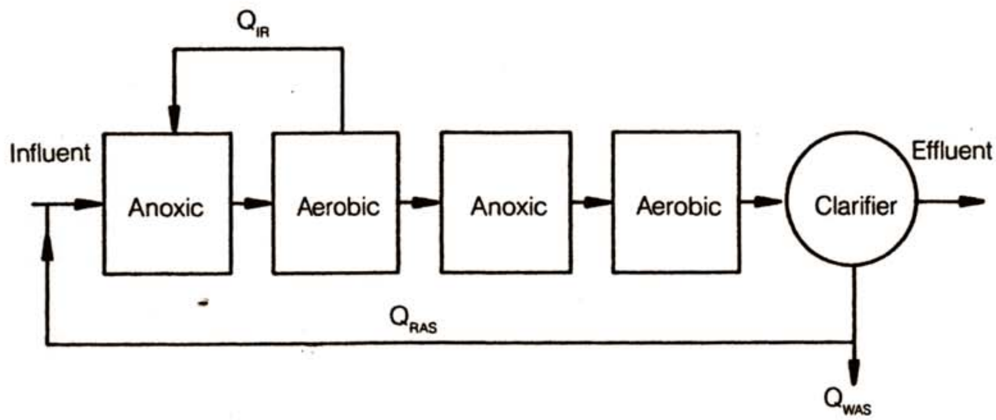
Modified Ludzack-Ettinger Process

EXHIBIT 6-6

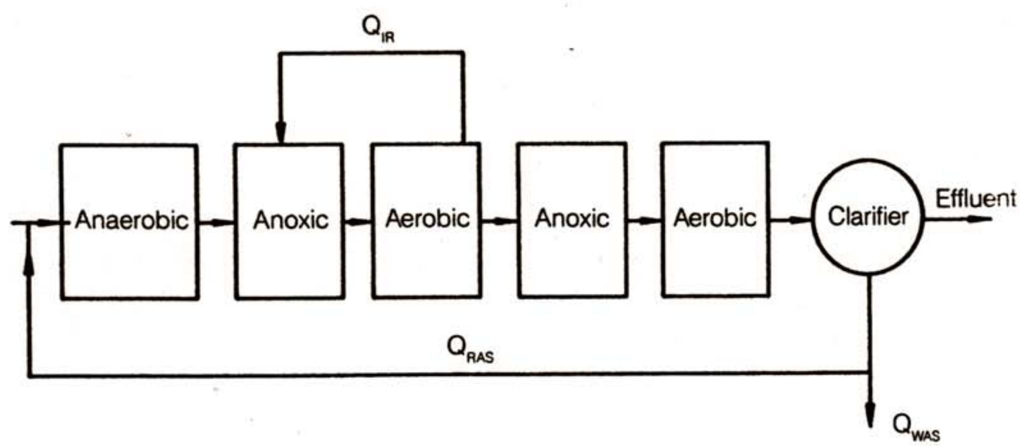
Source: Design of Municipal Wastewater Treatment Plants, 4th Edition

Manual of Practice 8

Water Environment Federation



Bardenpho™ Process for Nitrogen Removal



Modified Bardenpho™ Process for Phosphorus & Nitrogen Removal

EXHIBIT 6-7

Source: Design of Municipal Wastewater Treatment Plants, 4th Edition

Manual of Practice 8

Water Environment Federation

vi. LemTec™ Process

The LemTec™ process is a lagoon-based system that consists of a series of aerobic and anaerobic cells. Its advanced treatment capabilities are largely confined to ammonia removal. Effluent concentrations as low as 2 mg/l are achievable according to process literature. The basic process consists of five phases. The first phase is a screening phase to remove matter greater than ¼ -inch. A complete-mix cell with a typical hydraulic detention time of four days is the second phase. This cell is usually covered for heat retention. Aeration in the second phase is provided by fine bubble diffusers and floating mechanical mixers. The third phase is a partial mix cell with up to three days detention time which is usually separated from the complete-mix cell with baffles. In this partial-mix cell, which is also covered, sufficient aeration is provided to maintain solids in suspension. The fourth phase is a settling area which is comprised of an anaerobic quiescent zone with a detention time of up to four days. It, like the complete-mix and partial-mix cells, are covered to retain heat. The fifth and final stage is a polishing cell which consists of attached-growth media modules that are aerated and submerged. These modules maintain adequate bacterial population for effluent polishing. When disinfection is required, this final polishing phase is omitted. Exhibits 6-8 and 6-9 are photos of components of the LemTec™ process.

EXHIBIT 6-8
COVERED CELL

EXHIBIT 6-9
AERATED CELL

b. Attached-Growth Biological Processes

i. ZenoGem® Membrane Bio-Reactors

Membrane filtration technology has emerged as a viable wastewater treatment method. The use of immersed ultra-filtration (UF) membranes in conjunction with high-rate activated sludge systems is proving to be an effective method of advanced treatment for both nitrogen and phosphorus removal. There are several membrane bioreactor (MBR) processes in use today. One such process is the ZenoGem® system in which the membranes, which have hollow cores, are immersed in a compartment (bio-reactor) containing aerated mixed liquor from a high-rate activated sludge system. The membranes are typically attached to a framed module in the bioreactor and are subjected to a gentle suction which pulls the mixed liquor to the inside of the membrane. In some other systems, a positive pressure is applied which pushes the mixed liquor from inside to the outside of the membrane. All suspended and colloidal solids, including bacteria in the mixed liquor, are retained on the wall of the membrane. The mixed liquor is biologically digested in the bio-reactor and re-circulated continuously to the membrane reactors. The mixed liquor which passes through the membranes, minus the suspended and colloidal matter retained on the membrane walls, is discharged from the system.

According to manufacturer reports, membrane bio-reactors can typically produce effluents with ammonia nitrogen and total nitrogen concentrations of less than 1 mg/l and 5 mg/l respectively.

ii. Bio^{2}Bloc® Biological Contact Reactors

Biological contact reactors have been used as an add-on process to activated sludge and lagoon systems to achieve ammonia removal. The Bio^{2}Bloc® system is such a process that has been used in Mississippi with some success. In this process, the reactor is filled with media on which a biomass attaches itself as the wastewater being treated passes through the reactor while air and water are supplied by fine bubble membrane diffusers located on the bottom of the reactor chamber. The reactors are typically located to receive the effluent from a lagoon or activated sludge system so that organic (BOD_5) reduction has been maximized. As the attached biomass increases in growth, it tends to become overgrown with organisms and thence requires backwashing to clear the reactor media for new growth. Backwashing is usually achieved via a coarse-bubble aeration system that is valved and controlled remotely. The manufacturer of this system reports that effluent ammonia concentrations of less than 1 mg/l can be achieved. Typical biological contact reactors are pictures in Exhibit 6-10.

EXHIBIT 6-10

BIOLOGICAL CONTACT REACTORS

iii. Denitrification Filters

Denitrification filters, consisting of granular media, typically follow a nitrification process and, in effect, combine both the physical process of filtration and the biological denitrification process. Bacteria attach themselves to the granular media and require a source of carbonaceous (organic) matter as a food source. Raw wastewater normally cannot be used for this purpose because the ammonia and suspended solids contents are too high. Instead, methanol is typically used for this food source.

As the bacteria in the filter convert nitrates to nitrogen gas, it becomes a necessary operational procedure to release the nitrogen gas from the filter to prevent excessive head loss across the filter. Said release is achieved by periodically backwashing the filter with water for a few minutes. The rate at which nitrogen releases are required is influenced by such factors as the nitrate concentration entering the filter, media depth, hydraulic loading, and media size and shape. Media depths usually range from 4-feet to 6 feet. Both sand and coal, in addition to synthetic materials, have been utilized as filter media. Most media are spherical in shape with sizes typically ranging from 1.8 mm to 3.65 mm.

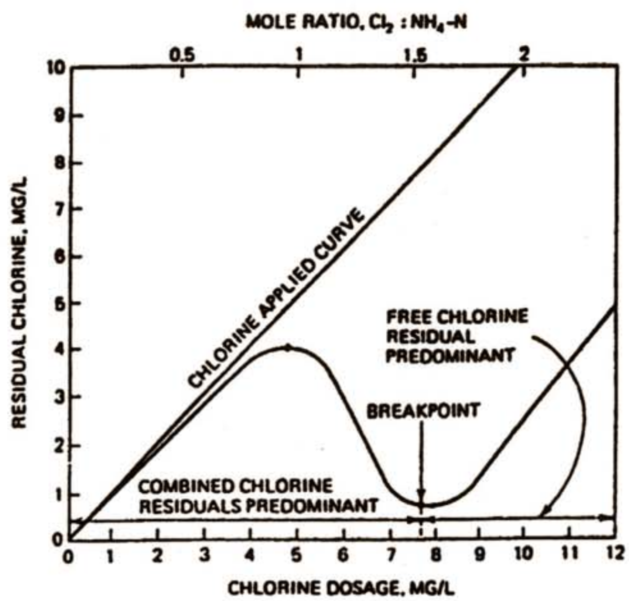
iv. Submerged Rotating Biological Contactors

Conventional rotating biological contactors, or RBC's, are used for both reducing carbonaceous organics (BOD_5) and for achieving nitrification. Such units typically operate with approximately 40% of the rotating contactor immersed in the wastewater being treated. However, in order to utilize the RBC process to achieve denitrification, a separate submerged unit is normally located following the conventional RBC and final clarification. Methanol, or some other suitable carbonaceous organic food source, must be fed to the submerged RBC. As with any methanol input, the feed rate must be controlled carefully so that the bacteria have sufficient food but not so much that carbonaceous matter (BOD) is added to the effluent.

c. Chemical Processes

i. Breakpoint Chlorination

Breakpoint chlorination can be utilized for removal of ammonia from treated effluents. When chlorine is added to wastewaters containing ammonia nitrogen, the ammonia reacts with the chlorine to form compounds called chloramines. Continued addition of chlorine to the wastewater will convert the chloramines to various end products which include primarily nitrogen gas along with nitrous oxide and nitrogen tri-chloride. Conversion of the chloramines to these end products occurs when the "breakpoint" is reached. The breakpoint, as illustrated in Exhibit 6-11, occurs when



BREAKPOINT CHLORINATION CURVE

EXHIBIT 6-11

Source: Handbook of Advanced Wastewater Treatment
Culp, Wesner & Culp
Van Nostrand Reinhold Company, New York, New York

sufficient chlorine has been added to reduce the combined chlorine residual to a minimum. Once this point has been reached, the free chlorine begins to increase.

The basic chemical reactions which lead to the formation of chloramines are as follows:

1. $Cl_2 + H_2O \rightarrow HOCl + H^+ + Cl$,
2. $NH_4 + HOCl \rightarrow NH_2Cl$ (mono-chloramine) $+ H_2O + H^+$,
3. $NH_2Cl + HOCl \rightarrow NHCl_2$ (di-chloramine) $+ H_2O$, and
4. $NHCl_2 + HOCl \rightarrow NCl_3$ (tri-chloramine) $+ H_2O$.

The overall breakpoint between the ammonium ion and chlorine which leads to the ultimate formation of nitrogen gas (N_2) can be simplified as follows: $NH_4^+ + 1.5\ HOCl \rightarrow 0.5\ N_2 + 1.5\ H_2O + 2.5\ H^+ + 1.5\ Cl^-$.

The breakpoint chlorination process requires rather strict controls and high chlorine dosages. The following operational factors must be addressed in operating a breakpoint system:

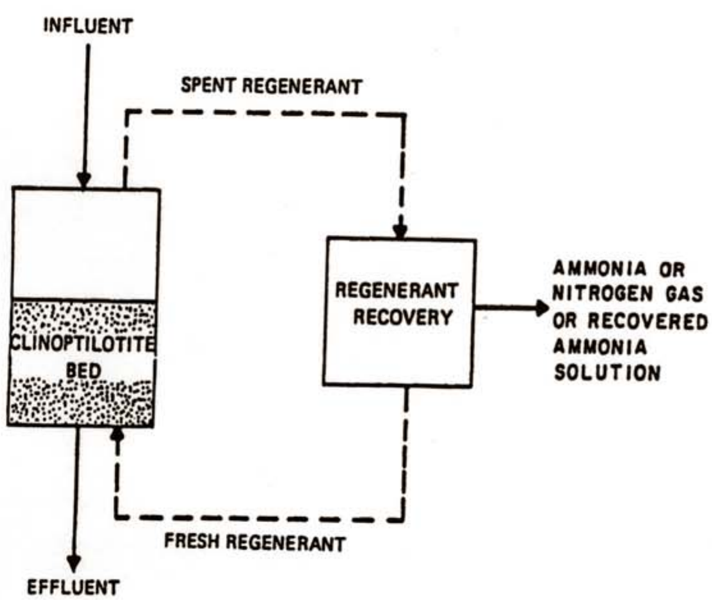
1. A weight ratio of chlorine to ammonia of 7.6:1 is needed to reach the breakpoint – which means that at least 7.6 parts of chlorine is needed for each part of ammonia converted;
2. The pH of the wastewater being chlorinated should be maintained in the range of 6 to 8;
3. A contact time of at least two hours is needed to reach the breakpoint; and
4. Monitoring of influent and effluent ammonia concentrations is needed to determine chlorine dosages.

The use of this process is not common primarily because of the high chlorine dosages required and strictness of controls necessary to safely achieve the desired results.

ii. Selective Ion Exchange

Selective ion exchange is a process used for ammonia removal in which ions on the surface of a solid material are exchanged for ions in a solution in which the solid material is immersed. In wastewater applications, ammonia ions are "exchanged" for the cations on the solid material in the exchange column. The ammonia ions remain in the exchange column and the cations from the column leave in the wastewater effluent.

Probably the most common exchange media in use today is clinoptilotite which is a zeolite that exists naturally in several extensive deposits in the western United States. Exhibit 6-12 illustrates a selective ion exchange process which uses a



SELECTIVE ION EXCHANGE PROCESS

EXHIBIT 6-12

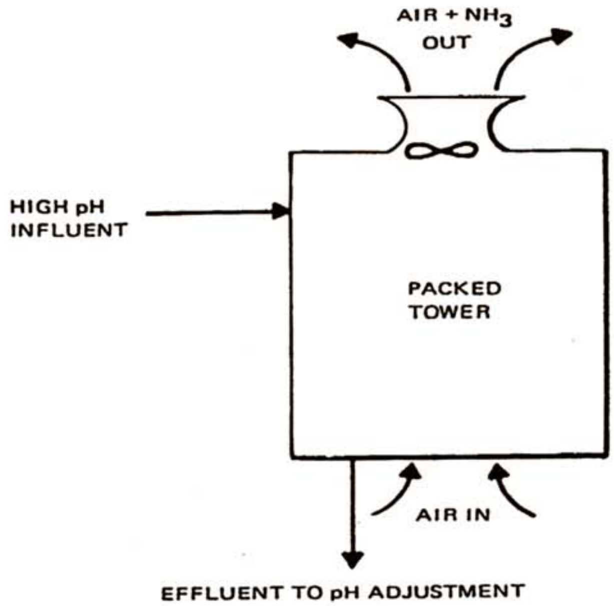
Source: Process Design Manual for Nitrogen Control
U.S. EPA, Technology Transfer

bed of clinoptilotite. The wastewater is passed downward through the clinoptilotite bed where the exchange of cation occurs. When the ammonia concentration in the bed increases to an objectionable concentration, the clinoptilotite is regenerated by passing a salt solution through the column to remove the ammonia. It is possible to achieve ammonia removals in the range of 90% to 95% with properly designed and operated exchange columns.

d. Physical Processes

i. Air Stripping

Air stripping is a very simple process which offers a reliable means of ammonia removal when properly applied. The process, as illustrated in Exhibit 6-13, consists three (3) basic steps. First, the pH of the wastewater is raised, usually by adding lime, to values in the range of 10.8 to 11.5. Secondly, water droplets are formed in a stripping tower that typically resembles a conventional cooling tower. And thirdly, air-water contact is provided by circulation of large quantities of air through the tower. The process simply results in the ammonia being "stripped" from the wastewater and discharged to the atmosphere as ammonia gas.



AIR STRIPPING PROCESS FOR AMMONIA REMOVAL

EXHIBIT 6-13

Source: Process Design Manual for Nitrogen Control
U.S. EPA, Technology Transfer

6-4 BASIC CONCEPTS OF PHOSPHORUS REMOVAL

a. The Need for Phosphorus Removal

Phosphorus is a normal and natural component of domestic wastewater. Human feces and urine, waste foods, and detergents comprise the major sources of phosphorus in wastewater. A typical concentration of phosphorus in raw domestic wastewater is approximately 10 mg/l. If wastewaters are comprised of discharges from sources other than domestic users, the phosphorus content can be significantly higher. Common industrial and commercial sources of phosphorus include wastewaters from the following: commercial laundries, dairies, potato processing plants, fertilizer manufacturing processes, animal feedlots, and slaughterhouses. Phosphorus is found in wastewater as orthophosphate, polyphosphate, or organic phosphate. During biological treatment, most phosphorus is converted to orthophosphate (PO_4^-). Consequently, phosphorus removal in wastewater is usually confined to removal of orthophosphate.

The removal of phosphorus from treated wastewater effluents is largely confined to locations where nutrient content is critical for the receiving stream. Phosphate is a nutrient which serves as a fertilizer and the growth of aquatic plants can thrive in its presence. In certain bodies of water, it is necessary to limit the amounts of fertilizing nutrients such as nitrates and phosphates which may be discharged in treated effluents to prevent excessive growths of algae and aquatic plants. Through a process known as eutrophication, such excessive growths result in large masses of algae and nuisance plants that can cause serious harm or even destroy the aesthetic value of a body of water.

b. Biological Phosphorus Removal

Biological phosphorus removal can be achieved by bacteria which naturally occur in domestic wastewater treatment systems. Such bacteria utilize phosphorus in their cell structures. When a state of "endogenous respiration" is provided, the bacteria oxidize some of their own cell mass. In such a state, bacteria are forced to metabolize their own cell matter because available food is at a minimum; and they absorb an excess amount of phosphorus into their cell mass through a process called "luxury uptake". When the bacteria are subsequently placed in an anaerobic environment void of oxygen, they release phosphorus. As phosphorus is released by the bacteria, it can then be removed from the wastewater by settling – usually with the aid of lime or other chemical precipitants. Phosphorus removal also occurs through the wasting of biomass containing excess phosphorus.

c. Chemical Phosphorus Removal

Chemical removal of phosphorus is achieved with the addition of flocculants and/or precipitants to the wastewater. Precipitants such as lime can be added in sufficient concentrations to raise the pH and produce compounds consisting of phosphorus, calcium, and hydroxyl ions. Through chemical reactions enhanced by gentle mixing, these compounds will form heavier solids (referred to as "floc") that will easily settle, or precipitate, when placed in a clarifier - thereby removing the phosphorus. The process of the heavier solids being formed is called flocculation. This process is often referred to as lime precipitation. A similar process involves the addition of a chemical agent such as alum (aluminum sulfate) or a polymer to create the floc. When alum is added as the flocculating agent, an aluminum phosphate floc is created. This floc is heavy and will settle to the bottom of a clarifier just like the lime precipitant. Beside alum, there are numerous commercially-available polymers that can be applied with equal effectiveness as a flocculating agent.

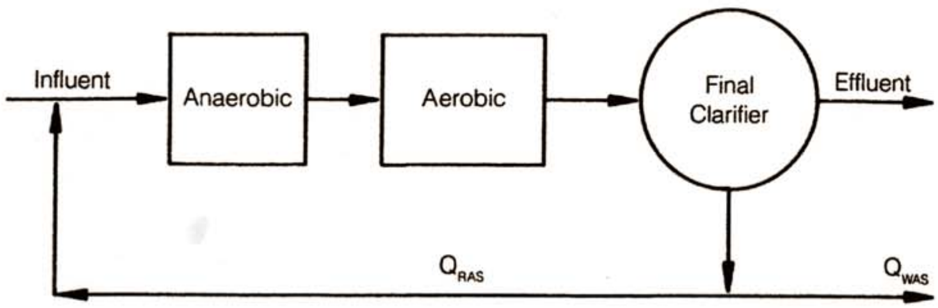
6-5 ADVANCED TREATMENT METHODS FOR PHOSPHORUS REMOVAL

a. Biological Processes

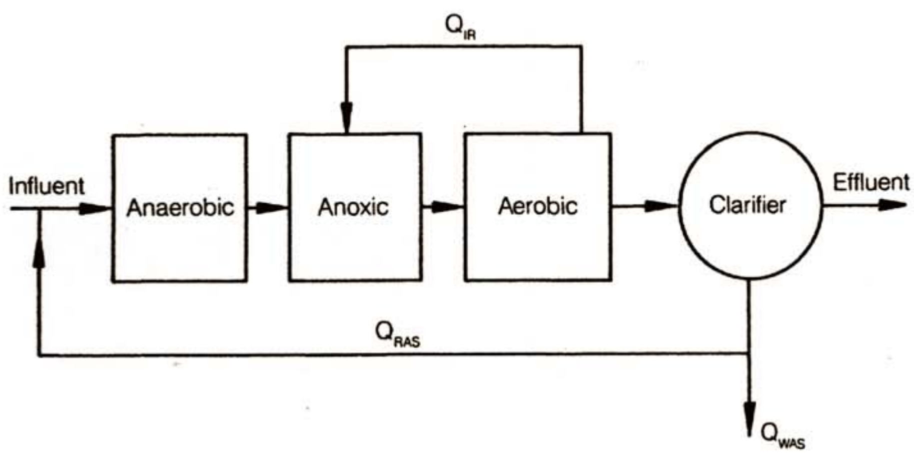
i. A/O™ Process

The A/O™ Process is used primarily for removal of carbonaceous matter (BOD) and phosphorus. The basic process consists of an anaerobic zone followed by an aerobic zone and a clarifier. Both the anaerobic and aerobic zones are completely mixed regimes. The process is more efficient at removing phosphorus when nitrification does not occur – which is typical for this process unless it is modified to provide longer detention in the aerobic zone. Should nitrification occur, the sludge that is returned from the clarifier back to the anaerobic cell will contain nitrates and may inhibit phosphorus removal.

A modification of the A/O™ Process, the A^2/O® Process, can be used if nitrogen removal is needed. This process includes more detention in the aerobic zone for nitrification and adds a third stage which is an anoxic zone for denitrification between the anaerobic and aerobic cells. Exhibit 6-14 depicts the components of both the A/O™ Process and the A^2/O® Process.



A/O™ Process for Nitrogen Removal



A^2/O™ Process for Phosphorus Removal

EXHIBIT 6-14

Source: Design of Municipal Wastewater Treatment Plants, 4th Edition

Manual of Practice 8

Water Environment Federation

ii. Modified Bardenpho™ Process

The Modified Bardenpho™ Process, sometimes referred to as a "5-Stage Bardenpho™ Process", is different from the basic Bardenpho™ process cited in Section 6-3.a.v for nitrogen removal because an anaerobic zone is added at the influent end of the process. This anaerobic zone, in conjunction with the anoxic and aerobic zones that are part of the basic Bardenpho™ process, allows the process to achieve phosphorus removal.

Exhibit 6-7, previously mentioned, depicts the basic components of the modified Bardenpho™ process.

b. Chemical Processes

i. Chemical Precipitation

Chemical precipitation is a commonly-used method for removing phosphorus from wastewater effluents. This method is simple, effective, and relatively inexpensive. The process simply involves the addition of chemical coagulants which react with phosphate ions to form precipitants that readily settle. Materials found to be most effective in precipitating (settling) phosphates include ionic forms of aluminum, iron, and calcium.

Probably the most common compound, or flocculation agent, used in precipitating phosphates from wastewaters is alum ($Al_2(SO_4)_3$). Iron compounds also used include ferrous sulfate, ferric sulfate, and ferric chloride. Calcium in the form of lime has also been used effectively.

The precipitant can be added to the wastewater treatment process at various points in the system. It is necessary that either a mixing device be included to mix the precipitant with the wastewater or that it be added to an aeration tank where mixing can be provided. Examples of applications that have been used successfully include the following:

1. Addition before primary clarifier,
2. Addition before secondary clarifier,
3. Addition to aeration tank (activated sludge), and
4. Addition to secondary effluent ahead of tertiary clarifiers.

6-6 PHYSICAL-CHEMICAL TREATMENT

The basic goals of treating domestic wastewater is to reduce pollutants such as suspended solids, organic matter, nitrogen, phosphorus, and pathogenic bacteria to acceptable levels prior to discharging the treated effluent to a stream. It has become common practice to utilize biological methods as the primary means for reducing these pollutants. However, reduction of pollutant levels can be achieved without biological methods by using strictly physical and chemical processes.

The process of chemical clarification, filtration, and carbon adsorption are most frequently used in "physical-chemical" systems. Clarification, through the use of coagulants, and filtration are used to achieve solids removal. Carbon adsorption is used to remove soluble organic matter. As in any conventional treatment process, preliminary treatment such as grit removal and comminuting as well as post-treatment such as disinfection and aeration are utilized with physical-chemical systems. Exhibit 6-15 depicts a schematic flow diagram of a typical physical-chemical treatment system.

The majority of pollutant removal in a physical-chemical treatment system is achieved by clarification. A chemical coagulant is mixed with the wastewater which significantly improves the settling characteristics. Chemicals typically used include organic polymers, ferrous sulfate, ferric chloride, alum, and lime.

The major role of the carbon adsorption process is removal of soluble organics. This process is necessary if a high quality effluent is to be produced. Beds or columns of granular carbon are normally used for the adsorption process. It is reasonable to expect 90% to 95% of soluble organics to be removed by these beds or columns. The wastewater is usually passed through the carbon for a contact time of thirty (30) to sixty (60) minutes.

Provisions must be made to periodically clean and regenerate the carbon granules. This is done by removing the carbon and heating in a furnace with steam to a temperature of about 1,750 °F.

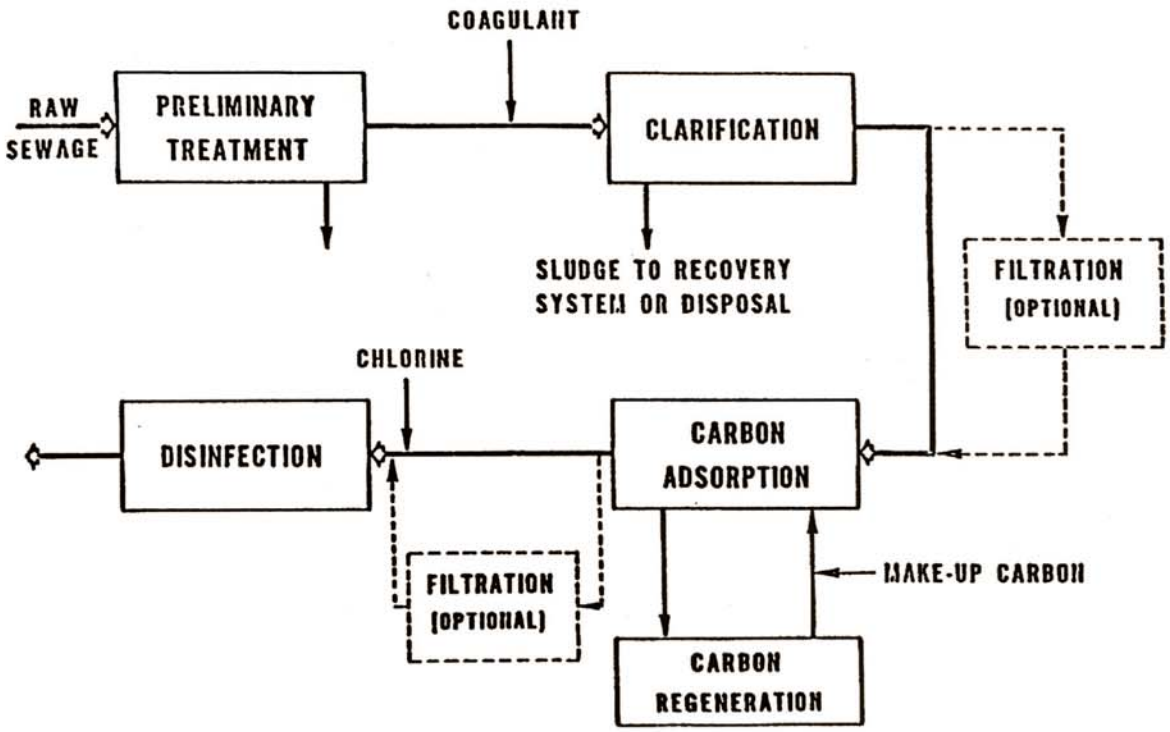


EXHIBIT 6-15

Source: Physical-Chemical Processes

U.S. EPA, Technology Transfer

CHAPTER 7

DISINFECTION

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CHAPTER 7

DISINFECTION

7-1 PURPOSE OF DISINFECTION

Disinfection results in the destruction of pathogenic (disease-producing) organisms. As a component in the overall treatment of municipal and domestic wastewaters, the process is typically applied to treated effluents prior to their discharge to a receiving watercourse. Although there are a variety of disinfection methods in use, the fundamental purpose of each is to destroy disease-producing organisms and thereby protect receiving waters from contamination.

Human feces, which comprise a significant part of municipal and domestic wastewater, can and usually will contain a variety of pathogenic microorganisms. In addition, there are numerous other microorganisms present in human wastes, such as coliform bacteria, which are not harmful to health but which merely serve as indicators of the likelihood of the presence of disease-producing organisms. The pathogenic organisms of greatest concern with regard to human exposure to waterborne diseases are enteric bacteria and viruses and intestinal parasites. Some of the more common pathogens and their associated diseases that may be found in municipal and domestic wastewaters include:

1. *Salmonella* typhosa (typhoid fever);
2. *Salmonellae* (milder typhoid-like illnesses);
3. *Shigella dysenteriae* (bacillary dysentery);
4. *Endamoeba histolytica* (amoebic dysentery);
5. *Mycobacterium tuberculosis* (tuberculosis);
6. *Vibrio cholerae* (Asiatic cholera); and
7. Viruses (hepatitis, poliomyelitis, and other diseases of viral origin).

The discharge of wastewater which has not been disinfected into a watercourse produces the potential for contamination by pathogenic organisms. Wastewater treatment facilities typically discharge their effluents to natural watercourses that are tributaries of larger bodies of water with downstream users. The use of bodies of water for such purposes as public water supply, recreation, shellfish harvesting, or crop irrigation can provide a means for the transmission of waterborne diseases. Hence, because municipal and domestic wastewaters contain human feces and the numerous organisms naturally present therein, it is necessary that disinfection be practiced prior to discharging to receiving waters so as to protect downstream users from waterborne diseases.

7-2 ALTERNATIVE DISINFECTANTS

There are several disinfectants which are used in treating wastewater effluents. Historically, the one most commonly used has been chlorine. However, concern over the potential carcinogenic effects of chlorine has led to increased use of other agents. Those disinfectants considered to be the most widely used in the treatment of municipal and domestic wastewater are as follows:

1. Chlorine - Chlorine is the most prevalent disinfecting agent in use today. It offers cost-effectiveness as an advantage over other alternatives in addition to its effectiveness against a wide variety of pathogens. Another advantage of chlorine is its long history of application as a disinfectant which results in established and known procedures for chlorination methods. Disadvantages include potential for toxicity to aquatic, estuarine, and marine organisms; the formation of carcinogenic compounds such as chloroform, bromoform, or chlorodibromomethane; and the need to provide for dechlorination. Chlorine disinfects by altering the permeability of cells which in turn interferes with the exchange between cells and their environment or causes leakage of cell contents.

2. Ultraviolet Irradiation - Next to chlorine, ultraviolet (UV) irradiation is the most popular technology utilized today for the disinfection of wastewater. The advantages of using UV irradiation include the absence of any toxic residuals; its effectiveness on a wide range of microorganisms; the small space occupied by the UV equipment; and relatively low costs. Disadvantages include a lack of measurable residual and subsequent control difficulties; the lack of a means of measuring/controlling dosage; and the possibility of photoreactivation which can repair cell damage achieved by disinfection. UV irradiation disinfects by directly attacking nucleic acids and causing distortions of DNA and subsequent cell destruction.

3. Ozone - Ozone is an allotropic form of oxygen, whose use as a wastewater disinfectant has emerged only recently. Advantages offered by ozone include the lack of a toxic residual; an increase in dissolved oxygen concentrations; almost instantaneous disinfecting action; and no dependency on pH and temperature for effectiveness. Disadvantages include higher initial costs and operational expense; required pilot testing to determine dosages; and somewhat unreliable automated control systems. Ozone disinfects by reacting with fatty acids in cell membranes which results in leakage of cell contents or a complete destruction of cells.

4. Bromine Chloride - Bromine chloride is a mixture of bromine and chlorine which has proven to be a more effective disinfectant than either of its individual components. Bromine chloride offers the advantages of being a more active disinfectant than chlorine; reacting over a wider pH range than chlorine; and having a faster reaction in less contact time. The major disadvantages include production of a "bromine demand" which exceeds a "chlorine demand"; high cost and limited availability; and difficulties with automated controls due to short-lived residuals. Disinfection using bromine chloride is achieved basically in the same manner as with chlorine where cell permeability is altered which leads to interference with exchanges between cells and their environment or leakage of cell contents.

5. Chlorine Dioxide - Chlorine dioxide gas is a popular bleaching agent used in the wood/pulp and textile industries. It has also been used for such purposes as taste/odor control, iron and manganese removal, algae control, prevention of THM (trihalomethanes) formation, and disinfection in water treatment. Advantages offered by chlorine dioxide include non-production of significant quantities of chlorinated or brominated organics as is the case with chlorine and ozone. In addition, it is effective over a broad pH range and is amenable to being retrofitted into existing chlorination facilities. The major disadvantages of using chlorine dioxide gas are its high cost and its explosive characteristics which require rigid safety precautions in its use. Chlorine dioxide disinfects by an oxidation reaction which alters amino acids and causes the interruption of various cellular processes.

Of the aforementioned disinfectants, current practices, dictated primarily by economic considerations, have resulted in chlorine, ultraviolet irradiation, or ozone being the most commonly used alternatives for treating municipal or domestic wastewaters. For this reason, more detailed information on their features and associated technologies are presented hereinafter.

7-3 CHLORINATION

a. Process Description

Chlorination was first used in the mid-nineteenth century on an emergency basis for disinfecting water supplies. Continuous chlorination of water supplies was initiated in England at the beginning of the twentieth century. The first attempt to continuously chlorinate a public water supply in the United States was in 1909 in Jersey City, New Jersey. Since that time, advances in chlorine handling equipment and facilities have led to the widespread use of chlorination for disinfection of both public water supplies and treated wastewater effluents.

Chlorine is an extremely active chemical that will react with many compounds to produce many different products. If a small amount of chlorine is added to wastewater, it will react rapidly with what is called reducing compounds (such as hydrogen sulfide, thiosulfate, and ferrous iron). Under these conditions, chlorine is converted to chloride and little or no disinfection will result. If excess chlorine remains after reaction with all such reducing compounds, it will react with ammonia and other nitrogenous matter to form chloramines. Again, if excess chlorine remains, it will react next with the organic compounds present to form chloro-organic compounds which have slight disinfecting action. Finally, if excess chlorine remains following all of the aforementioned reactions, the additional chlorine will form free available chlorine which has the highest disinfecting properties. Consequently, to accomplish disinfection, sufficient chlorine must be added to satisfy the chlorine demand and leave, after a specified contact time, a residual chlorine that will destroy organisms. Both chlorine dosage and contact time are, therefore, essential to organism kill.

The relationship between chlorine dosage, demand, and residual is expressed mathematically as follows:

$$\text{Demand} = \text{Dosage} - \text{Residual}.$$

Chlorine dosage is simply the amount of chlorine applied. Demand is normally defined as the portion used by the reaction of chlorine with the organic and inorganic reducing substances. Residual is the amount of chlorine remaining after the demand has been satisfied for a specified period of time. It should be noted that although significant kill of sensitive organisms occurs while the chlorine demand is being satisfied, disinfection is caused primarily by the residual.

The chlorine residual may be expressed as a "total" residual, "free" residual, or "combined" residual. It is common practice to refer to chlorine gas (Cl_2), hypochlorous acid (HOCl), and hypochlorite ion (OCl-) as free chlorine residuals. Combined chlorine residual is usually used to refer to chloramines, which are compounds created when ammonia reacts with chlorine or hypochlorous acid. Total chlorine residual, which is commonly used in effluent monitoring in Mississippi, is simply the sum of all chlorine substances which have disinfecting properties.

Chlorination is normally achieved in wastewater applications by utilizing one of the following:

1. Chlorine gas (Cl_2),
2. Calcium hypochlorite ($Ca(OCl_2)$), or
3. Sodium hypochlorite (NaOCl).

Chlorine gas is a chemical element which is non-explosive and non-flammable. It is greenish-yellow in color and weighs approximately 2.5 times as much as air. Although it is not typically used in wastewater applications, chlorine can also exist in liquid form. One volume of liquid chlorine will produce about 460 volumes of chlorine gas when the liquid is vaporized. When chlorine gas is used, it normally is mixed with water to form a chlorine solution immediately prior to being added to the liquid (treated effluent) being disinfected. Calcium and sodium hypochlorites are chlorine compounds which exist in solid form (tablets or powder)or liquid; and when used for wastewater disinfection, they are normally added directly to the wastewater.

In recent years, due to growing concern over toxic effects of chlorinated effluents on fish and other aquatic organisms, regulatory agencies have begun requiring de-chlorination following disinfection to remove all or part of the chlorine residual remaining after chlorination. Sulfur dioxide (SO_2) is by far the most commonly used de-chlorination agent in wastewater applications.

Sulfur dioxide, like chlorine, is a non-flammable compressed gas and is stored and shipped commercially in steel cylinders. SO_2 gas is colorless with a suffocating, pungent odor and is about 2.25 times as heavy as air. In the presence of sufficient moisture, sulfur dioxide is corrosive to most common metals. SO_2 is an extremely irritating gas that may cause varying degrees of irritation to the eyes, nose, throat, and lungs because of sulfurous acid formation. When SO_2 is applied to chlorinated wastewater, it reacts instantaneously with free and combined residual chlorine to yield small amounts of acidity, which in turn is usually neutralized by the alkalinity of the wastewater. As a general rule, one part of sulfur dioxide is applied for each part of residual chlorine to be removed.

b. Applications

In wastewater treatment, chlorination is typically used for two purposes. The primary use is effluent disinfection. In addition, the process is sometimes used for "pre-chlorination".

In pre-chlorination applications, chlorine is normally added at or near the head of a treatment facility for such purposes as slime-growth control, corrosion control, odor control, removal of oil and grease, reduction of BOD, destruction of filamentous organisms to control bulking sludge, foam control, and flies/insects control. Table 7-1 lists the typical chlorine dosages required for pre-chlorination uses. Care should be exercised in selecting and applying chlorine dosages for pre-chlorination so as not to inhibit or upset biological processes which may follow the point of application.

As the term implies, the use of chlorine for effluent disinfection involves the application of chlorine to the effluent from a wastewater treatment facility. Disinfection has as its purpose the destruction of disease-producing organisms. The dosage of chlorine required for disinfection varies with the quality and characteristics of the treated effluent. Table 7-1 also lists typical dosages for various types of wastewater effluents.

There are several factors which influence the effectiveness of using chlorination for disinfection. These include the following:

1. Injection Point - The chlorine substance should be applied where the wastewater enters the contact tank. An air gap or backflow prevention device should be provided to prevent cross-connection of potable water supply and wastewater.
2. Mixing - Sufficient mixing of the chlorine and the wastewater is necessary. Baffles are usually constructed in chlorine contact tanks to maximize detention time and enhance mixing.
3. Contact Time - Usually a minimum of 30 minutes contact time is needed to assure disinfection.
4. Efficiency of Treatment Process - Disinfection is more effective in the effluent from an efficient treatment process than from a process with poor efficiency.
5. Temperature - The rate of disinfection increases as the temperature increases.
6. Type of Chlorine Source - Gaseous application is more effective than hypochlorites.
7. pH - Disinfection is more effective in wastewaters with lower pH values.

TABLE 7-1

CHLORINATION APPLICATIONS & DOSAGES

APPLICATION		TYPICAL DOSAGE
I.	Pre-Chlorination	
	Slime-growth Control	1 to 10 mg/l
	Corrosion Control (H_2S)	2 to 9 mg/l per mg/l of H_2S
	Odor Control	2 to 9 mg/l per mg/l of H_2S
	Oil & Grease Removal	2 to 10 mg/l
	BOD Reduction	0.5 to 2 mg/l per mg/l of BOD Reduced
	Sludge Bulking	1 to 10 mg/l
	Foam Control	2 to 15 mg/l
	Fly Control	0.1 to 0.5 mg/l
II.	Disinfection	
	Untreated Wastewater	5 to 25 mg/l
	Primary Effluent	5 to 20 mg/l
	Trickling Filter Effluent	3 to 15 mg/l
	Activated Sludge Effluent	2 to 8 mg/l

c. Gaseous Chlorination Systems

Most chlorinators in use at wastewater treatment facilities are vacuum-operated solution feed gas chlorinators. The purpose of any chlorinator is to feed the chlorine into the liquid being disinfected. In vacuum-operated gas chlorinators, chlorine gas is mixed with water to form a chlorine solution which is then fed directly into the liquid being disinfected. Water under pressure flows through a device called an ejector (or injector, depending on the manufacturer). The velocity of the flowing water creates a vacuum in a line connected to the ejector and the chlorinator, which is located either directly on the cylinder valve or on a manifold from the cylinder. The vacuum activates the chlorinator which allows chlorine gas to flow through the line to the ejector where it mixes with the flowing water to form a chlorine solution. The chlorine solution is then discharged into the liquid being disinfected.

The water supply to the ejector can be from a community's potable supply if the water pressure is sufficient. If no community supply is available or if inadequate water pressure is available, a small booster pump can be used to force clarified effluent through the ejector or to simply increase the water pressure and subsequent velocity so that sufficient vacuum will be pulled.

The rate at which chlorine solution is fed into the liquid being disinfected can be controlled by various methods. The most common rate controls are as follows:

1. Manual Control Adjustment - This adjustment consists of manually turning a knob on a flow meter installed in the vacuum line between the cylinder and the ejector.
2. Step Rate Control - This method is sometimes used when the flow being chlorinated is pumped. The chlorinator feed rate is adjusted automatically according to the number of pumps in operation.
3. Flow Proportional Control - The feed rate is adjusted automatically according to the rate of flow of the wastewater being chlorinated. Adjustment is normally done in response to electrical signals relayed from a flow-measuring device.

4. Chlorine Residual Control - The feed rate is adjusted automatically to maintain a desired chlorine residual. The residual is monitored automatically and a signal is sent electronically to a control device which regulates the feed rate.
5. Compound Loop Control - The feed rate is adjusted automatically by utilizing two or more of the aforementioned automatic controls. Such a system obviously provides the greatest degree of dependability, but also requires more operational attention.

Virtually all feed rate control devices are calibrated in units of "lbs/day" or "lbs/24 hours". Exhibit 7-1 is a schematic drawing of a conventional wastewater chlorination system utilizing 150-pound cylinders and a vacuum-operated gaseous chlorinator with manual feed-rate control.

An optional device with which many gaseous chlorinators are installed is an "automatic switchover" module. This device provides automatic switching from one chlorine cylinder when it is emptied to another full container. Such a device obviously helps to assure continuous chlorination.

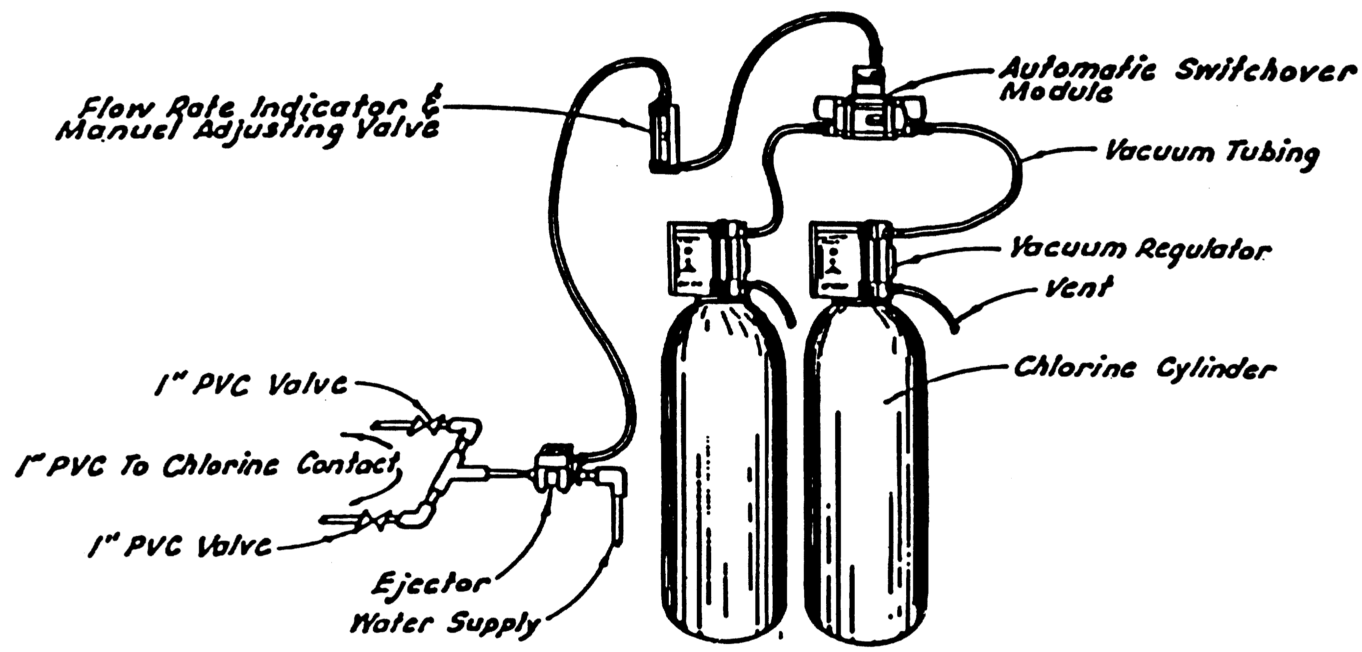
Chlorine gas is normally supplied in steel containers, into which liquified chlorine is compressed. The most common sizes of these containers are those containing 100, 150, and 2,000 pounds of compressed liquid chlorine. Most treatment facilities which require a chlorine dosage of less than 40 to 50 pounds per day utilize the 150 pound cylinders. Larger facilities utilize the 2,000 pound cylinders. Because the liquified chlorine is placed in the cylinders under pressure, it is discharged as a gas when released from the top of the cylinder. Exhibit 7-2 shows two examples of the 150 and 2,000 pound cylinders in use. Table 7-2 lists the approximate dimensions and weights of common cylinders.

The 100 to 150 pound cylinders are seamless and have only one opening as required by Federal regulations. This opening is for the valve connection at the top of the cylinder. A steel valve protection hood is provided to cover the valve. Most cylinders in the 100 to 150 pound range are equipped with a "standard cylinder valve" as illustrated in Exhibit 7-3. These valves are equipped with a fusible metal type safety plug. The fusible metal is designed to melt at temperatures between 158° F and 165° F. When the plug melts, pressure is relieved and rupture of the cylinder is prevented in case of fire or other exposure to high temperatures.

The one-ton (2,000 lb.) cylinders are welded tanks with the heads made convex inward. The sides are usually crimped inward to provide a safe grip for lifting. Two identical valves are usually placed near the tank's center at one end. The valves, which are illustrated in Exhibit 7-3 differ from those on the 100- and 150-pound cylinders in that they have no fusible metal plug and have a larger internal passage. Each valve is protected by a removable steel protection hood. Fusible metal safety plugs are normally constructed in the end of the tank. It is common to have three (3) plugs in each end. The melting temperature of the fusible metal is the same as that used in the smaller cylinder valves (158 to 165° F).

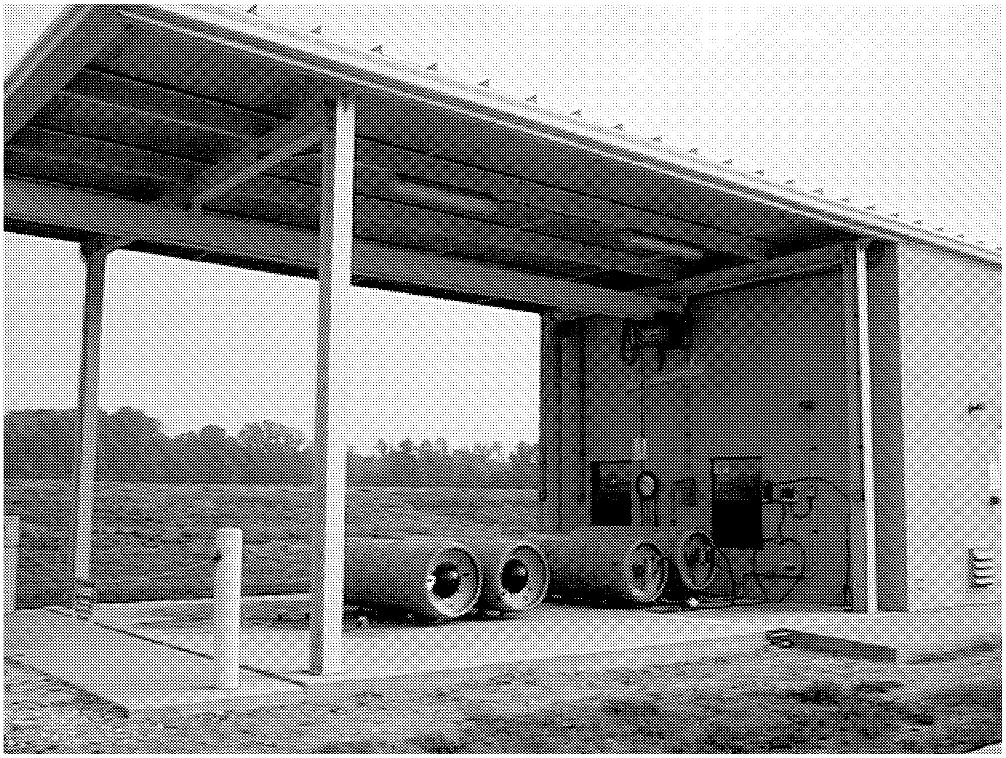
Specially made chlorine valve wrenches should always be used to open and close cylinder valves. Using conventional wrenches can exert too much force which can damage the valve and create leaks. Cylinders with valves which can not be opened with a chlorine valve wrench should be returned to the supplier.

There are numerous problems which can develop with a chlorination system. Most of these are normally associated with chlorine feed equipment. Table 7-3 contains a summarized listing of the more common problems, their indicators, evaluation procedures, and general corrective measures.

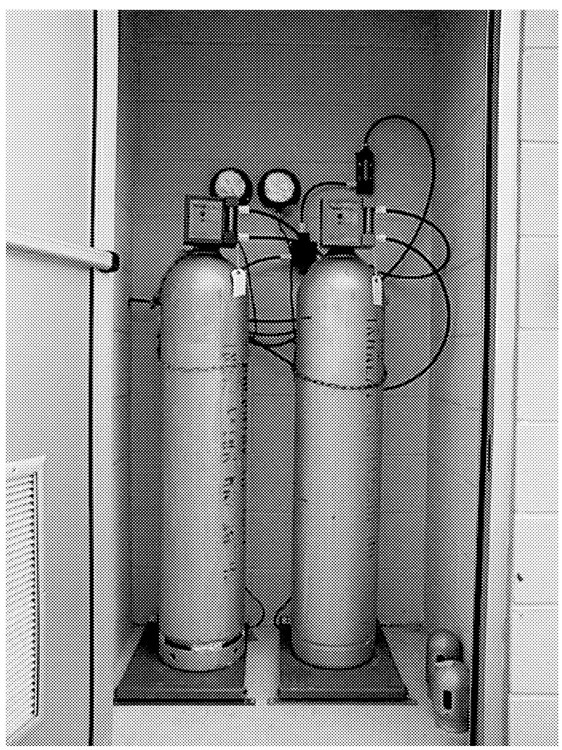


DIRECT CYLINDER-MOUNTED CHLORINATOR
W/AUTOMATIC SWITCHOVER

EXHIBIT 7-1



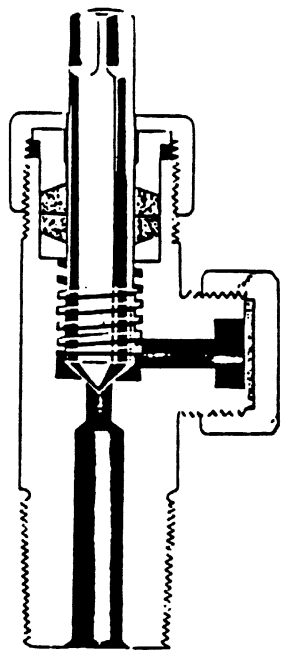
ONE TON CONTAINERS



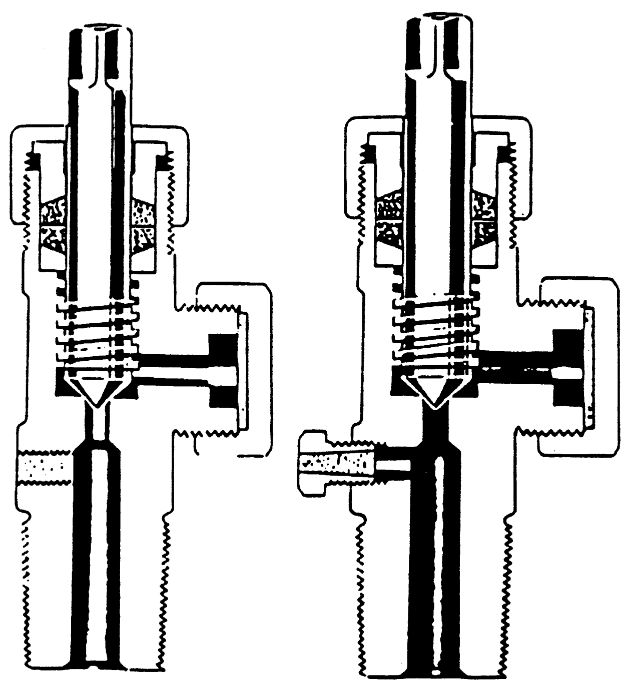
150 POUNDS CYLINDERS

EXHIBIT 7-2

CHLORINE GAS CONTAINERS



Standard Valve for Ton Containers



Standard Cylinder Valves for 150-Pound Cylinders
Poured Type Fusible Plug(Left) & Screwed Type Fusible Plug(Right)

EXHIBIT 7-3

STANDARD CHLORINE CYLINDER VALVES

Source: Chlorine Institute, Inc.

TABLE 7-2
DIMENSIONS AND WEIGHTS
OF
CHLORINE CYLINDERS

CAPACITY	Weight CLASS	Empty* Weight (Lbs.)	Outside Diameter (In.)	Overall Height or Length** (In.)
100	Heavy	80-115	8¼ - 8½	53-59
100	Light	63-79	8¼ - 8½	53-55
100	Heavy	95-105	10½ - 10¾	40-43
100	Light	63-76	10½ - 10¾	39½-43
105	Heavy	85	10¼ - 10½	41⅛
105	Light	72-77	10¼ - 10½	40-41
105	Light	72-77	8¼ - 8½	57-58
150	Heavy	120-140	10½ - 10¾	53-56
150	Light	85-105	10¼ - 10¾	53-56
2,000	-	1,300 - 1,650	30	79¾ - 82½

Source: Chlorine Manual, The Chlorine Institute, Inc.

NOTES:
* Weight includes protection hood and valve.
** Height is to top of protection hood; height to centerline of valve outlet is approximately 3½ inches less.

d. <u>Hypochlorination Systems</u>

Calcium hypochlorite ($Ca(OCl_2)$) or sodium hypochlorite (NaOCl) can be used in chlorination systems instead of chlorine gas (Cl_2). Both of these chlorine compounds exist in a dry solid state, usually as tablets or a powder. Sodium hypochlorite is also available as a liquid. Their use in wastewater chlorination is usually confined to very small treatment plants.

Hypochlorinators are devices which feed the dry solid chlorine compounds into the wastewater being chlorinated. Devices are available which feature both tablet-feed or powder-feed. In powder-feed systems, dry chlorine powder is mixed with water to form a slurry which is then introduced into the wastewater by a metering pump. While hypochlorinators are usually relatively inexpensive, their effectiveness in disinfecting wastewater is normally not nearly as good as gaseous chlorinators. Exhibit 7-4 shows both tablet-feed and liquid-feed hypochlorinators in use.

e. <u>Contact Tanks</u>

Once chlorine has been injected into wastewater, it is necessary that sufficient time be provided for the disinfection process to take place before the chlorinated water is discharged. As a general rule, at least thirty (30) minutes of the "contact" time is needed to assure that a chlorination system is providing adequate disinfection. The necessary "contact" between the chlorine and wastewater is normally provided in a chlorine contact tank.

The chlorine is usually injected in the wastewater as it enters the contact tank. Baffles are commonly constructed in the tank to assure that the chlorinated wastewater flows through the complete volume of the tank; thereby eliminating hydraulic short-circuiting and providing maximum detention or "contact" time.

TABLE 7-3
COMMON OPERATING PROBLEMS, CAUSES & CURES
GAS CHLORINATION

PROBLEM	INDICATORS/OBSERVATIONS	POSSIBLE CAUSE	EVALUATION PROCEDURE	REMEDIES
Loss of Chlorine feed	1. Flow meter shows little or no indication of chlorine flow when the feed rate adjustment knob is turned from a closed to a wide open position.	A. Dirty or plugged nozzle in the ejector-diffuser.	1. Remove the Chlorine gas line at the ejector and hold thumb over fitting. Suitable vaccum will exert a strong pull. If there is no vacuum, the ejector nozzle may be plugged.	1. Clean ejector nozzle as per manufacturer's instructions.
		B. Insufficient water pressure to operate ejector-diffuser.	1. Remove the chlorine gas line at the ejector and hold thumb over fitting. Suitable vacuum will exert a strong pull. If there is no vacuum, water pressure could be in-sufficient. Check building water pressure at con-venient hose bibb.	1. If water pressure is insufficient, a booster pump should be installed. Contact the manufacturer's representative.
		C. No Chlorine Supply.	1. Check supply indicator at regulator.	1. Replace empty cylinder with full one.
		D. Plugged chlorination inlet filter.	1. Remove fiber glass filter and check.	1. Replace fiber glass as per manufactur-er's instructions.
Chlorine Leak	1. Chlorine odor; leaks revealed when system checked with ammonia solution; corrosion & discoloration at leak source.	A. Faulty Chlorine cylinder valve packing.	1. Confirm location of leak with ammonia solution.	1. Tighten cylinder valve packing nut without exerting excessive force.

Table 7-3 (continued)

PROBLEM	INDICATORS/OBSERVATIONS	POSSIBLE CAUSE	EVALUATION PROCEDURE	REMEDIES
Chlorine Leak (cont)				2. If tightening the packing nut does not not eliminate the leak, close the valve and call the chlorine supplier.
		B. Faulty gasket seal between the chlorinator and the chlorine cylinder valve due to re-use of gasket, dirt on gasket, under- or over-tight connection.	1. Confirm location of leak with ammonia solution	1. Install new gasket; make certain the gasket surfaces are clean and smooth. Tighten clamp, but not excessively.
		C. Leak at safety shut-off valve.	1. Confirm location of leak with ammonia solution.	1. Before removing the unit from the cylinder, close the cylinder valve, turn on the water supply and allow the chlorinator to operate until the metering ball drops to the bottom.
			2. Check to see if chlorine is leaking out of the vent - a leak here usually means a leak at the shut-off valve.	
			3. Shut-off water supply to ejector and submerge the end of the vent tubing in a glass of water. Continuous bubbling is an indication of a leak.	2. Clean shut-off valve and seat in accordance with manufacturer's instructions.

Table 7-3 (continued)

PROBLEM	INDICATORS/OBSERVATIONS	POSSIBLE CAUSE	EVALUATION PROCEDURE	REMEDIES
Sticky Ball in Chlorine Meter	1. Erratic movement of ball in flow meter.	A. Trace organic compounds in chlorine gas deposit themselves on the ball or glass tube.	1. Remove meter assembly and examine for "sticky" ball.	1. Clean meter assembly in accordance with manufacturer's instructions.
Vacuum Leak	1. Ball in flow meter does not drop to bottom when the cylinder valve is shut-off.	A. Leak in chlorine meter gasket because meter is not installed straight or meter is plugged.	1. Confirm location of leak with ammonia solution.	1. Replace gasket with new one. Tighten meter plug sufficiently, but do not tighten excessively.
		B. Worn rate valve O-ring.	1. Confirm location of leak with ammonia solution.	1. Replace O-rings as per manufacturer's instructions; if fouled metal surface caused abrasion of the O-ring - replace this unit also.
		C. Leak in sealing surface at main diaphragm due to fouled surface or spec of dirt on surface.	1. Confirm location of leak with ammonia solution.	1. Clean surface and re-assemble.
Chlorine gas leaking from vent line.	1. No visible indication of a malfunction; chlorine gas escaping from vent line; gas pressure, feed rate and vacuum are all normal.	A. Ruptured pressure relief valve.	1. Confirm leak with ammonia solution. 2. Disassemble control unit by closing off gas supply from cylinder and allow time for chlorine in chlorinator to escape-inspect valve to see if failure is from corrosion, improper assembly,or wear and tear.	1. Replace valve as per manufacturer's instructions.

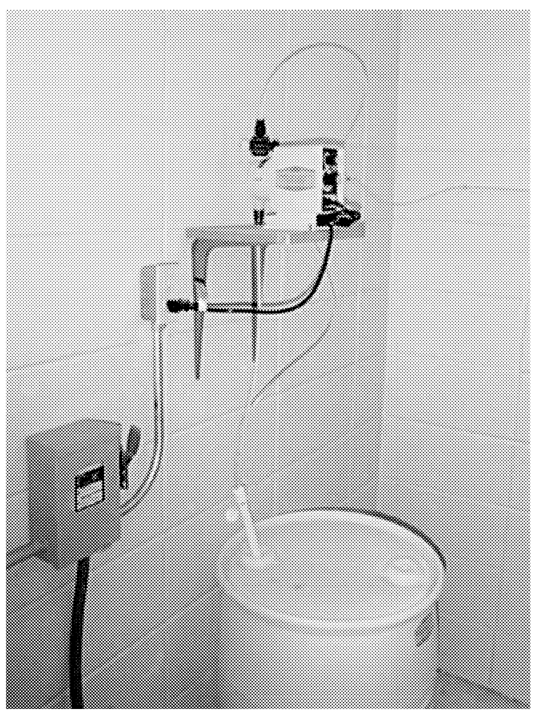
Table 7-3 (continued)

PROBLEM	INDICATORS/OBSERVATIONS	POSSIBLE CAUSE	EVALUATION PROCEDURE	REMEDIES
Excessive chlorine odor at point of application	1. Air above area of application in contact tank reacts with ammonia solution to produce white whisps of "smoke".	A. Insufficient water supply to ejector.	1. Confirm excess chlorine in area with ammonia solution. 2. Check position of valve on water line to ejector.	1. Increase water supply to ejector by opening water valve more. Enough water should be added to bring the chlorine solution strength down to 3500 mg/l chlorine at the maximum expected feed rate.
Chlorinator will not feed enough chlorine to produce a proper chlorine residual.	1. Spot check sampling shows that at some hours of the day there is an adequate residual but there are times during the day when there is no residual.	A. Contact tank has excessive solids build-up or dosage is inadequate.	1. Check to be sure chlorination capacity is adequate to provide desired feed rate. 2. Evaluate dosage. 3. Determine if solids have settled to bottom of contact tank.	1. Increase dosage and/or clean tank as needed.
Chlorine is being withdrawn from two cylinders at once.	1. Indicators on both vacuum regulators indicate cylinders are in use.	A. Vacuum leak or insufficient vacuum at ejector.	1. Refer to procedures for "Vacuum Leaks."	1. Refer to remedies for "Vacuum Leaks."
Automatic switch over does not occur.	1. Indicator on initial vacuum regulator indicates "no chlorine" but other cylinder shows no flow through flow tube.	A. Supply valve closed on second cylinder.	1. Check supply valves - both must be open.	1. Open supply valves on both cylinders.
		B. Second cylinder is empty.	1. Check second cylinder to be certain it is not empty.	1. Replace with full cylinders.

Table 7-3 (continued)

PROBLEM	INDICATORS/OBSERVATIONS	POSSIBLE CAUSE	EVALUATION PROCEDURE	REMEDIES
		C. Linkage may be bound bound or dirt has fouled the O-ring seal within the module.	1. Remove the module and disassemble as per manufacturer's instructions. 2. Remove linkage and spring assembly - clean with alcohol. 3. Examine O-ring seals and clean with alcohol. If hardened or distorted, replace.	1. Replace or clean O-ring, clean linkage and spring assembly and re-assemble as per manufacturer's instructions.
Switch over occurs before first cylinder is empty.	1. Excessive chlorine withdrawal.	A. Pressure drop within cylinder caused by high withdrawal rate.	1. Allow system to operate from second cylinder as the first will regain pressure as it is warming. 2. When second cylinder empties or pressure decreases, the system will switch back to the first cylinder.	1. Replace emptied cylinders. 2. Reduce feed rate.

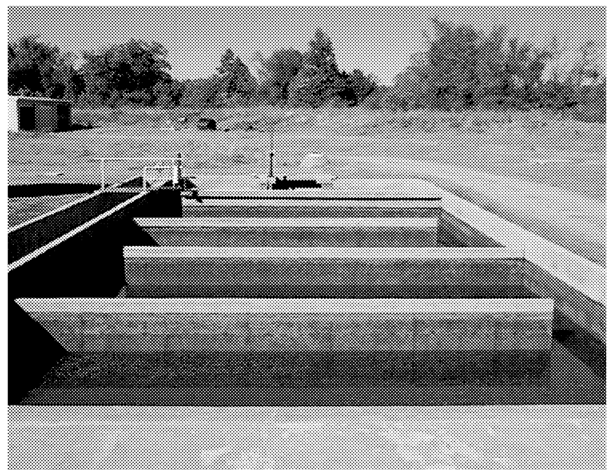
TABLET CHLORINATOR



METERING PUMP CHLORINATOR

EXHIBIT 7-4

HYPOCHLORINATORS



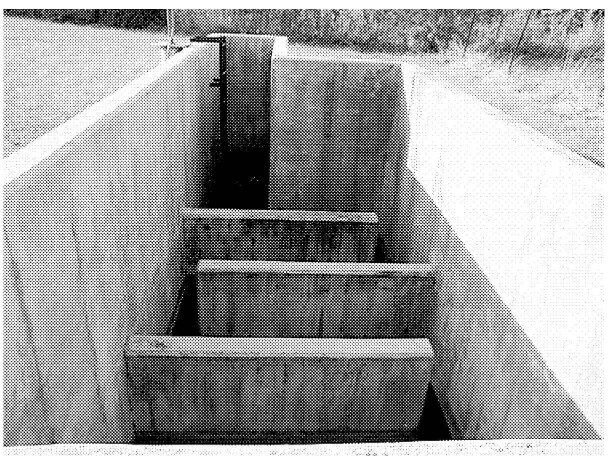


EXHIBIT 7-5

CHLORINE CONTACT TANKS

f. Sulfonation (De-Chlorination) Systems

Chlorine residuals in treated effluents are most commonly reduced through the use of sulfur dioxide applied at the rate of approximately one part per part of chlorine residual to be removed. The process of applying sulfur dioxide to treated effluents is achieved through the use of vacuum-operated solution feed gas feeders like those used for gaseous chlorination. Sulfur dioxide, like chlorine, is supplied in steel pressure vessels of 100, 150 and 2,000 pound capacities. The gas feed systems for sulfonators are the same type as used for chlorinators; wherein sulfur dioxide gas is mixed with water to form a sulfur dioxide solution that is fed directly into the water (treated effluent) being de-chlorinated. Feed rates for sulfur dioxide solution are controlled with the same type systems used for chlorine solutions.

g. Laboratory Controls

There are two major parameters utilized to control and evaluate the effectiveness of a chlorination/de-chlorination system. These parameters are fecal coliform and chlorine residual. The Office of Pollution Control establishes effluent limitations for each of these parameters. Fecal coliform counts (colonies/100 ml) are used as indicators of the effectiveness of disinfection (bacterial kill). Chlorine residual concentrations (mg/l) are used to monitor and evaluate the effectiveness of the de-chlorination process. The specific effluent limitations for a treatment facility are largely determined by the size and use-classification of the receiving stream.

A description of the analyses required for each of the parameters is as follows:

1. Fecal Coliform - The coliform group is often specified as the primary standard for effectiveness of disinfection. It has been established that the bacteria causing diseases are less resistant to the chlorine than non-pathogenic intestinal bacteria, designated as the coliform group. For this reason, the destruction of the coliform group of bacteria generally provides an effective criteria for wastewater disinfection. The coliform group of organisms is a bacterial group that has as one of its primary habitat the intestinal tract of human beings. These non-pathogenic organisms may also be found in the intestinal tracts of other warm-blooded animals, and in plants, soil, air, and aquatic environments.

   The bacterial species of the coliform group, which is entirely of fecal origin, is referred to as "fecal coliforms". The fecal coliform group mainly includes the general Escherichia Coli group. Fecal coliform counts expressed as the number of colonies per 100 milliliters are usually required by regulatory agencies as a requirement for testing the effectiveness of disinfection as well as for establishing bacterial criteria for surface water quality.

2. Chlorine Residual - Chlorine residual is the amount of chlorine remaining after the chlorine demand has been satisfied following a specified contact period, usually at least thirty (30) minutes. The chlorine residual test is extremely important since low residuals will not provide the necessary disinfection while high residuals are objectionable because chlorine is a highly toxic substance to fish and other aquatic life.

h. Chlorine/Sulfur-Dioxide Hazards

The most common causes of accidents involving chlorine gas are leaking connections and over-chlorinating. Chlorine leaks are very dangerous since the gas is an irritant to the nose, throat, and lungs; causes violent coughing; and, in large concentrations, will cause death. To locate a chlorine leak, the following procedure is recommended:

> Tie a cloth to the end of a long stick, soak the cloth with aqua ammonia and hold close to the suspected area. A white cloud will result if there is any chlorine leakage. Commercial 26-degree Baume` aqua ammonia should be used.

Chlorine odor is detectable at a concentration of 3.5 mg/l in air; 4 mg/l is the maximum concentration that can be breathed for one hour with no adverse effects; 15 mg/l causes throat irritation; 30 mg/l causes coughing; 40 mg/l to 60 mg/l is dangerous when inhaled for thirty (30) minutes or more; and 1,000 mg/l can cause death after five (5) minutes exposure.

Because the characteristic sharp odor of chlorine is noticeable even when the amount in the air is small, it is usually possible to get out of the gas area before serious harm is suffered. This feature makes chlorine less hazardous than gases such as carbon monoxide, which is odorless, and hydrogen sulfide, which impairs the sense of smell in a short time.

Inhaling chlorine causes general restlessness, panic, severe irritation of the throat, sneezing, and production of much saliva. These symptoms are followed by coughing, vomiting, and difficulty in breathing. Chlorine is particularly irritating to persons suffering from asthma and certain types of chronic bronchitis. Liquid chlorine causes severe irritation and blistering on contact with the skin.

Chapter 13 of this manual can be consulted for further information on first aid procedures and general safety practices in handling chlorine, including the use and storage of gas masks and air packs.

As with chlorine, care needs to be taken in using and handling sulfur dioxide. Sulfur dioxide gas is extremely irritating to the eyes, nose, throat, and lungs because of sulfurous acid formation. Hence, it is imperative to check for and guard against leaks. A sulfur dioxide leak reveals itself by the pungent odor of sulfur dioxide gas. A leak can be located much like a chlorine leak by holding a cloth soaked with aqua ammonia over points of suspected leaks. Dense white fumes will form near a leak.

Sulfur dioxide gas is detectable at a concentration of 3 to 5 mg/l; 8 to 12 mg/l will cause irritation to the throat; 20 mg/l will irritate the eyes and induce coughing; 100 mg/l is the maximum concentration that can be tolerated for short periods; and 400 to 500 mg/l are acutely irritating to the upper respiratory system and will cause a sense of suffocation.

Sulfur dioxide gas is heavier than air and is corrosive to most common metals in the presence of sufficient moisture. Dry sulfur dioxide, liquid or gas, is not corrosive to steel and other common metals, except galvanized materials. Sulfur dioxide is neither flammable nor explosive in either the gaseous or liquid state. Because it neither burns nor supports combustion, there is no danger of fire or explosion.

Because chlorine and sulfur dioxide are considered hazardous substances, containers in which they are held must be handled and stored with care. The following procedures are suggested for properly handling 100, 150, and 2,000 pound cylinders:

1. When moving containers, valve protection hoods should be in place.
2. Containers should not be dropped and no object should be allowed to strike them with force.
3. Containers should be loaded onto and removed from trucks to a dock at truckbed height. If a hydraulic tail gate is used, containers must be prevented from falling.
4. A properly balanced hand truck with a clamp or chain at least two-thirds of the way up the cylinder should be used to move 100 and 150 pound cylinders. When cylinders must be lifted, an approved crane or hoist should be used. Cylinders should never be lifted with a sling, magnetic devices, or chains. Cylinders should never be lifted by the valve protection hood because the neckring to which the hood is attached is not designed to carry the weight of the cylinder.

5. Ton cylinders should be handled with a suitable lifting beam in combination with a crane or hoist of at least two (2) tons capacity.
6. 100 and 150 pound cylinders should be placed in an upright position and securely fastened to a wall or other sturdy structure with chains, ropes or braces.
7. Ton cylinders should be placed on their sides and carefully chocked or clamped on cradles to prevent shifting or rolling.

Certain precautions should be taken in storing chlorine and sulfur dioxide. Suggested procedures include the following:

1. If cylinders are stored indoors, the storage area should be designed and constructed to protect the systems from fire. If flammable materials are stored in the same building, a fire wall should be erected to separate the two areas. All exit doors in the storage area should open outward. It is desirable to provide at least two exits. Containers should not be stored near central air conditioning or heating ducts or elevators where dangerous concentrations of chlorine or sulfur dioxide may spread rapidly if a leak occurs. It is recommended that storage rooms be ventilated to the atmosphere with some type of floor-level forced air ventilation system. Chlorine and sulfur dioxide should be stored in separate areas.
2. If containers are stored outdoors, the storage area should be clean and free from accumulation of trash that might present a fire hazard.
3. Cylinders should not be stored in standing water or in areas where moisture is prevalent. A dry cool place is highly recommended.
4. Cylinders should not be stored where they can fall, drop or be hit by falling objects or moving vehicles.
5. Exposure of cylinders to flame, intense heat, or high temperature steam lines must be avoided. If the metal in the fusible safety plug reaches 158 degrees F, the plug will melt and chlorine or sulfur dioxide gas will escape. Intense local heat will increase corrosion of the steel cylinders; if the steel reaches 483 degrees F, it will ignite.
6. Full and empty containers should be stored in separate areas.
7. Valve outlet caps and protection hoods should be in place on all cylinders not in use, both empty and full.
8. 100 and 150 pound cylinders should be placed in an upright position and securely fastened to a wall or other sturdy structure with chains, ropes or braces.
9. Ton cylinders should be placed on their sides and carefully chocked or clamped on cradles to prevent shifting or rolling.

7-4 ULTRAVIOLET IRRADIATION

a. Process Description

Ultraviolet irradiation is emerging as an effective and economical alternative to chlorination as an effective means of disinfecting treated wastewater effluents. Shortwave ultraviolet (UV) light produced by low pressure mercury arc lamps is the normal mechanism by which the process provides disinfection. The disinfection caused by the UV light is a physical process that relies on the transfer of electromagnetic energy from the lamp to an organism's cellular genetic material (DNA). When the UV energy is absorbed by the DNA of an organism, changes are produced that prevent propagation of the organism. Of interest is the fact that it is possible for repair of damaged cellular material caused by UV light to occur if the damaged organisms are exposed to sunlight or light from most incandescent and fluorescent sources. This repair process is known as photoreactivation and does not affect all organisms to the same degree. If necessary for permitting reasons, measures can be taken in the design of an ultraviolet system to prevent or minimize potential photoreactivation.

b. Equipment

UV lamps are typically long thin tubes with lengths of 2.5 feet to 5.0 feet and diameters in the range of 0.60 inch to 0.80 inch. Radiation (ultraviolet light) is generated by striking an electric arc through mercury vapor; and UV light is thence emitted by the energy discharged by excitation of the mercury. The lamps can be suspended outside the liquid (treated effluent) being disinfected or submerged in the liquid. Exhibit 7-6 depicts the features of a typical submerged UV system and Exhibit 7-7 shows actual UV system in operation.

c. Laboratory Controls

There is no measurable residual with which to monitor ultraviolet disinfection as there is with chlorination (chlorine residual). However, because there is no toxicity introduced into the water (effluent) by UV light as there is with chlorine, the need to monitor a specific parameter is less. The overall effectiveness of the UV disinfection process currently is evaluated and controlled only with the fecal coliform analysis as previously described for chlorination.

d. Safety Considerations

Assuming that common sense is applied, ultraviolet irradiation is a safe process. Because the disinfecting agent (UV light) is produced on site, there are no materials transportation or storage precautions with which to be concerned. Most safety concerns with UV systems are directed toward electrical hazards and physical facilities such as grating and handrailing. Power supplies require high voltage; and thus, strict compliance with normal electrical safety precautions is absolutely essential. Used lamps need to be re-packaged for safe disposal when they are replaced. While submerged and operating, ultraviolet lamps do not present any hazard from excessive UV radiation because the radiation is weakened by water absorbance. However, the lamps should not be operated while in a dewatered and dry state. Skin and eyes are vulnerable to erythema (sunburn) produced by the absorption of UV radiation; and prolonged exposure to lamps operating in a dry state can create a hazard in this regard. In addition, absorption of UV light by the mucous membranes of the eyes can cause a condition known as "welder's flash" which, though painful and incapacitating, is usually temporary.

7-5 OZONATION

a. Process Description

The use of ozone as a disinfectant was pioneered in Europe for potable water. Its use as a wastewater disinfectant, however, has largely emerged in the United States, with most of the development occurring since 1970. There is speculation that the widespread use of ozone in wastewater technologies is on the verge of becoming a reality. Ozone (O_3) is a triatomic allotrope of oxygen which has a pungent odor. Ozone is generated on site by applying a high voltage alternating current across a dielectric gap that contains an oxygen-bearing gas. The oxygen-bearing gas can range from air to high-purity oxygen, with the higher productivity being with the latter or oxygen-enriched air. Ozone is typically introduced into the liquid (treated effluent) through the use of contactors such as bubble diffusers, positive pressure injectors, negative pressure, mechanical agitators and packed towers. The contact system provides for the mass transfer of ozone out of the gas bubbles into the liquid while

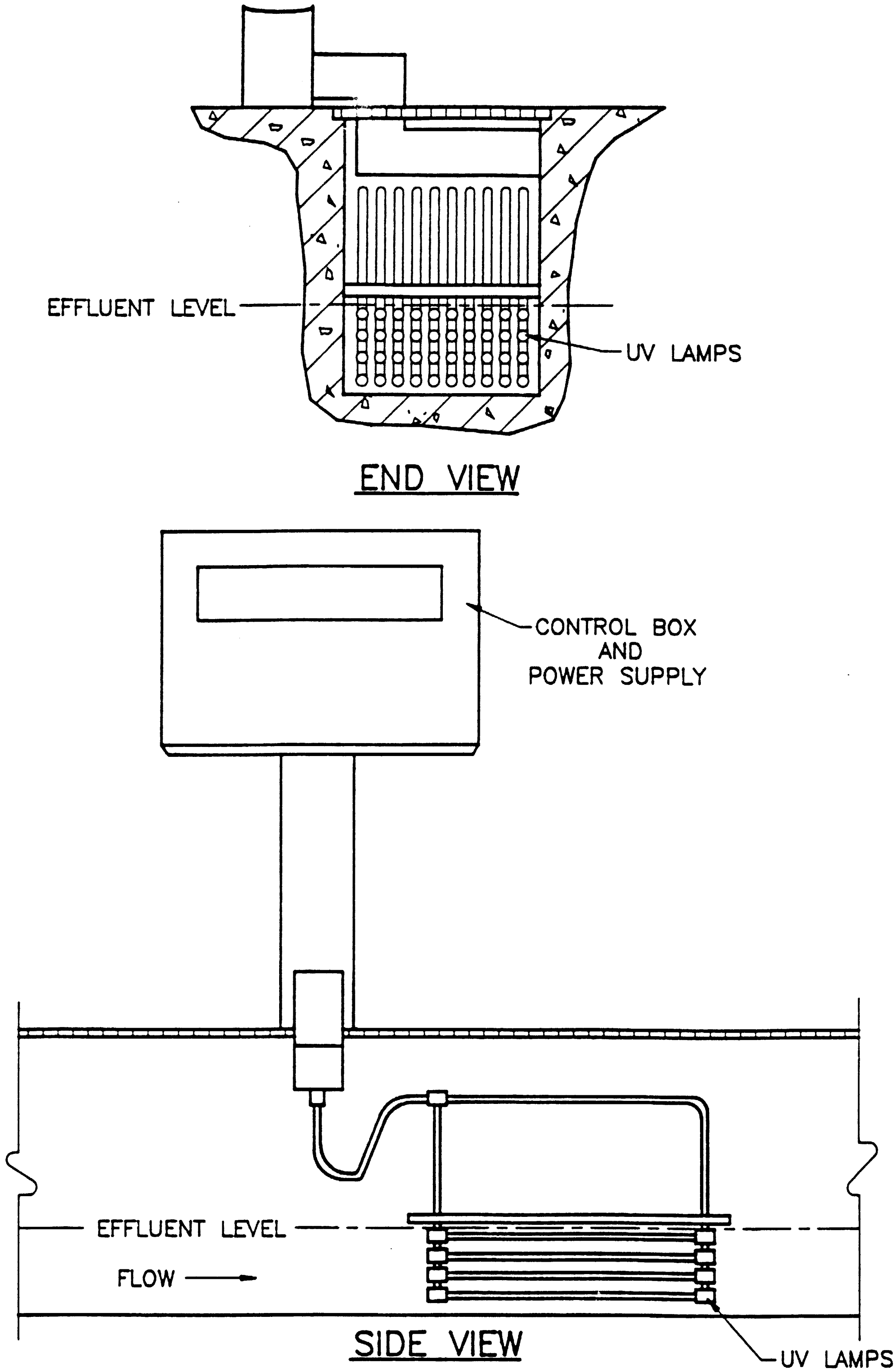
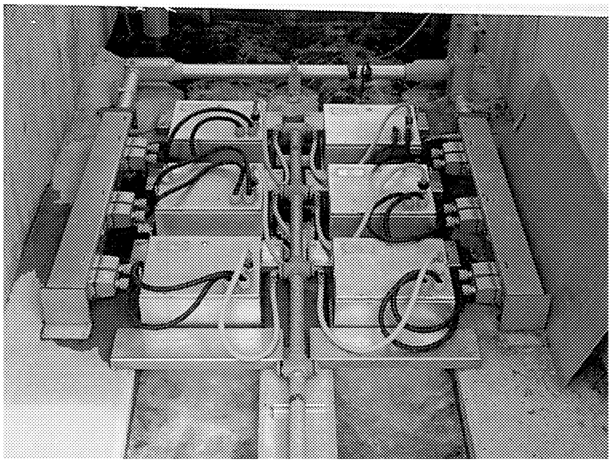


Exhibit 7-6

ULTRAVIOLET DISINFECTION SYSTEM



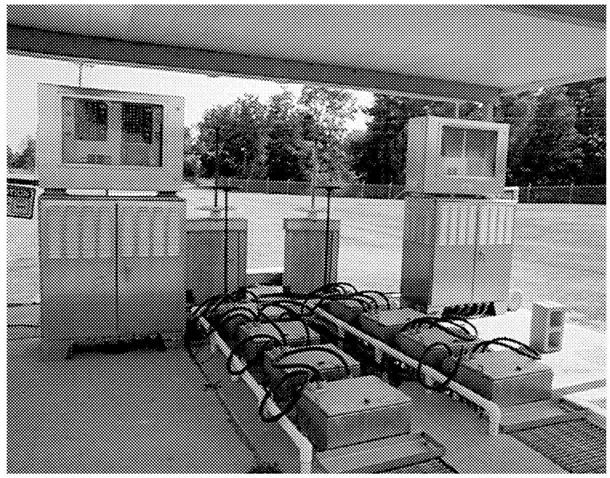


EXHIBIT 7-7

ULTRAVIOLET LIGHT DISINFECTION SYSTEMS

providing sufficient time for disinfection to occur. Disinfection is achieved by the reaction of ozone with fatty acids in cell membranes which results in a leakage of cell contents or complete cell destruction.

b. Equipment

The major equipment items required for ozonation systems include a gas preparation system, electrical power supply, ozone generator, ozone contactor, and an off-gas destructor. The gas preparation system, which usually includes a dessicant drier and filter, must deliver a clean feed gas to the ozone generator. The electrical power system is a critical component of any ozonation system and monitoring thereof is crucial to assure that every watt of power applied maximizes the amount of ozone produced. The ozone generator requires operation to control the applied voltage which in turn controls the amount of ozone produced. The ozone contactor delivers the ozone to the liquid being disinfected in such a manner as to allow sufficient ozone transfer and time for disinfection to take place.

c. Laboratory Controls

There are two (2) laboratory controls which can be utilized to evaluate and control the effectiveness of an ozonation system for wastewater disinfection. One of these is the fecal coliform analyses which has been previously cited for both chlorination and ultraviolet irradiation systems. This test simply provides an overall evaluation of the degree of bacterial disinfection being provided. Another parameter which can be monitored and used as an evaluative/control tool is ozone residual. There is more than one analytical procedure available to determine ozone residual, but the net result of any procedure allows the operator to assess the ozone demand, compare it to the bacterial (fecal coliform) count, and thence make adjustments as needed in ozone generation.

d. Safety Considerations

Ozone is considered to be a toxic substance which has a maximum allowable exposure for an 8-hour period of 0.10 mg/l. Basic effects of ozone on humans include detectable odor at concentrations of 0.015 to 0.10 mg/l; irritation of nose and throat at 0.10 mg/l; difficulty in breathing at 0.5 to 1.0 mg/l; and pulmonary edema, congestion, hemorrhage, and possible death at 1.0 to 10.0 mg/l. Exposure to concentrations of 1 mg/l for periods of thirty (30) minutes or longer will normally produce headaches. The underlying fact is that ozone is toxic and can be dangerous.

Properly calibrated ozone monitoring systems should be provided and maintained in work areas. Typically, said systems should sound an alarm at levels of 0.1 mg/l, deactivate generators, and activate ventilation systems. Ozone generators and associated piping should be purged prior to opening the systems for any purpose. Ozone contactor zones should be checked for ozone content and dewatered and vented prior to any personnel entering. Interiors of contactors should be tested for ozone, oxygen, and gaseous contaminants such as hydrogen sulfide by personnel wearing protective clothing and breathing apparatus prior to being entered.

CHAPTER 8

SLUDGE TREATMENT AND DISPOSAL

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CHAPTER 8

SLUDGE TREATMENT AND DISPOSAL

8-1 REASONS FOR SLUDGE TREATMENT/DISPOSAL

The term "sludge" is used to describe the settled suspended solids encountered in wastewater treatment. Suspended solids are a major component of domestic sewage and as such are one of the two major pollutants which most wastewater treatment facilities are designed to remove - the other being organic matter (BOD). Additional suspended solids are usually generated during the various wastewater treatment processes. Primary clarifiers, when provided, are the first source of sludge generation in a wastewater treatment facility. The settleable matter which is collected in a primary clarifier is generally referred to as "primary sludge". In virtually all biological treatment systems, the basic objective is to remove the organic matter (BOD) by converting it, through the various biological processes, to suspended solids which will settle when placed in a secondary clarifier. This suspended matter includes the "floc" or "mixed liquor suspended solids" from an activated sludge process and the "sloughings" from a trickling filter process. A certain portion of the sludge collected in a secondary clarifier may be returned or recirculated through the main biological process to maintain balance and enhance treatment efficiency. However, a portion also must typically be removed from the main processes and handled separately.

Once the solids have, through the process of settling, been collected in the bottom of a clarifier, the term "sludge" is then generally used to describe those solids for the remainder of their existence. It is obvious that solids or "sludge" will continue to build up in a treatment process and that measures must be taken to remove the collected sludge and do something with it since it contains most of the pollutants (BOD and suspended solids) which a treatment facility is designed to remove. However, in order to protect the environment, collected "raw" sludge cannot be simply removed and discarded. Instead, it must be treated and disposed of in a way that will not cause environmental damage.

The reasons for providing proper treatment of wastewater sludge prior to final disposal can be summarized as follows:

1. Raw sludge typically contains a large (60% to 80%) amount of organic matter. By treating sludge, it becomes "stabilized" which means that the organic content has been reduced to a level where biological activity is minimal.
2. Raw sludge, because of its organic content, produces offensive odors. Treatment of the sludge serves to eliminate odors.
3. Treatment of sludge will minimize the presence of pathogenic bacteria.
4. The volume of sludge that must be finally disposed of can be significantly reduced through treatment by converting solid matter to gases and liquid. The gases can be burned off or used as fuel and the liquid can be evaporated or returned to the main treatment process.
5. Treatment of sludge will allow it to be more easily handled, such as allowing it to be dewatered, dried, and thence placed in a landfill or used for soil conditioners, fill material, etc.

8-2 SOURCES/CHARACTERISTICS OF SLUDGE

a. Sources

In general terms, it can be said that sludges originate from the solids in raw wastewater and the various treatment processes used to treat the wastewater. However, in more specific terms, sludges can be categorized into the following process sources.

1. Primary Sludge - "Primary sludge" or "raw primary sludge," as it is sometimes called, is the sludge which is removed in a primary clarifier. This sludge is high in organic content and contains such things as oil and grease, garbage, fecal solids, grit, and other inorganic debris.
2. Secondary Sludge following Trickling Filter - Secondary sludge following a trickling filter is comprised of the "sloughings" or "humus" which have been washed from the filter media and settled out in a secondary clarifier. This sludge is typically mixed with primary sludge before removal and treatment.
3. Secondary Sludge following Activated Sludge - Secondary sludge following an activated sludge process is comprised of the "floc" or "mixed liquor suspended solids" which have been removed from the aeration basin and settled out in a secondary clarifier. This sludge makes up both "return activated sludge" and "waste activated sludge" as described in Chapter 5.
4. Chemically Precipitated Sludge - Chemically precipitated sludge or "chemical sludge" is comprised of sludge removed by the process of chemical coagulation where the addition of chemicals such as alum, lime, polymers, etc, cause the solids to coagulate or clump together and settle. This type sludge is commonly found in physical-chemical treatment systems or other "advanced" systems and in systems treating certain poor-settling industrial wastes such as those from a metal-plating operation.
5. Combined Sludge - Combined sludge generally refers to a mixture of primary and secondary sludges.
6. Digested sludge - Digested sludge is any of the above-mentioned sludges which has been subjected to anaerobic or aerobic digestion.

Table 8-1 contains a general description of these various sludges.

b. Physical Characteristics

The physical characteristics of sludges produced in wastewater treatment can vary greatly depending on the characteristics of the wastewater being treated and the design and operation of the treatment facility. It is important, however, to describe certain common characteristics which are important to the operation of sludge handling facilities. The more pertinent physical characteristics of sludges encountered in treatment of domestic wastewater are as follows:

1. Specific Gravity - Specific gravity is defined as the ratio of the weight of a material to that of an equal volume of water. In many instances wastewater sludges are assumed to have specific gravities of 1.00; i.e. the same weight as water (8.34 pounds per gallon or 62.4 pounds per cubic foot). However, in reality, the actual specific gravity of most sludges is in the range of 1.01 to 1.03 due to the solids content which is heavier than water. A sludge with a specific gravity of 1.02 would weigh 1.02 times as heavy as water (1.02 x 8.34 = 8.51 pounds per gallon).
2. Solids Content - The relative amounts of solid and liquid matter in sludges are described by the solids concentration expressed either in units of milligrams per liter (mg/l) or percent (%) solids. By assuming a specific gravity of 1.00, the following is true:

   $$10{,}000 \text{ mg/l} = 1\% \text{ solids},$$

   where, % solids is based on the ratio of weight of solids (dry weight) to weight of solids plus liquid (wet weight). Any concentration of sludge in mg/l can be converted to % solids (and vice versa) by ratioing the above. Also, it can be assumed that the following is true:

   $$\% \text{ moisture} = 100\% - \% \text{ solids}.$$

TABLE 8-1

CHARACTERISTICS OF COMMON WASTEWATER SLUDGES

SLUDGE	TYPICAL CHARACTERISTICS
Primary Sludge	Usually gray in color, extremely offensive odor, usually contains less than 6% solids.
Secondary Sludge (Trickling Filter)	Brownish color, flocculant, slight odor, readily digested, usually contains less than 2% solids.
Secondary Sludge (Activated Sludge)	Brown color, flocculant, little odor, becomes septic rapidly, biologically active, usually contains less than 2% solids.
Digested Sludge (Aerobic)	Brown to dark brown in color, flocculant, slight musty odor, dewaters easily, usually contains less than 4% solids.
Digested Sludge (Anaerobic)	Dark brown to black in color, contains large amounts of gas; slight odor when well-digested, usually contains less than 4% solids.

In other words, a sludge that contains 2% solids by weight is 98% moisture (water) by weight. The solids content of sludges vary considerably depending on the source of the sludge as previously shown in Table 8-1. However, it is common to find solids contents in the range of 0.5% to 10% solids (5,000 mg/l to 100,000 mg/l).

3. Distribution of Water - Liquid content of sludge typically comprises 90% to 99.5% of the sludge by weight. Most of the liquid is comprised of “free” water or water in the conventional sense. However, there are other forms of water which make-up various sludges and influence dewatering characteristics:

   a. Free Water - Water which is not attached to sludge solids and can be easily removed by evaporation and gravity settling such as drying beds.

   b. Floc Water - Water which is trapped within sludge (floc) particles and moves with them; mechanical dewatering is necessary for removal.

   c. Capillary Water - Water which adheres to sludge particles and can be squeezed out only if the individual particles are forced out of shape and compacted.

   d. Particle Water - Water which is chemically bound to the individual sludge particles.

   e. Intracellular Water - Water which is contained inside the biological cells and can only be removed by destroying the cell. Typically removed by heat conditioning or digestion.

4. Color and Odor - The color and odor of sludge varies with the sludge source (See Table 8-1).

c. Chemical Characteristics

Since many sludges have a relatively high concentration of organic material, they also have a significant fuel value. Dry sludge may have a fuel value of 10,000 BTU/pound of dry volatile solids. This compares to coal which has a fuel value of about 14,000 BTU/pound. However, because sludges are wet, the actual fuel per pound of sludge (wet weight) is only about 1,000 BTU/pound.

Wastewater sludges contain significant amounts of nutrients such as nitrogen, phosphorus, and potassium. However, the nutrient content is considerably less than that of most common fertilizers such as "8-8-8," which contains 8% nitrogen, 8% phosphorus, and 8% potassium. Table 8-2 lists typical nutrient contents of common wastewater sludges. In addition to nutrients, wastewater sludges may contain certain undesirable substances such as heavy metals, DDT, and PCB, all of which can be considered as toxins. Their presence limits the desirability of sludge as fertilizer, pending additional study and research.

d. Biological Characteristics

Wastewater sludges contain a wide variety or organisms. It is common to find bacteria, molds, yeasts, protozoa, crustaceans, and rotifers in sludges, depending on their origin and state of decomposition. Raw primary sludge typically has a high concentration of pathogenic organisms. Digestion, both anaerobic and aerobic, normally will destroy most pathogens. However, it is known that Salmonella bacteria can survive digestion.

TABLE 8-2

NUTRIENT CONTENT OF WASTEWATER SLUDGES

SLUDGE	% Nitrogen N	%Phosphorus P_2O_5	%Potassium K_2O
Primary	2.4 to 2.9	1.1 to 1.6	-
Secondary/Trickling Filter	2.9	2.8	-
Secondary/Activated Sludge	3.0 to 5.6	2.8 to 7.0	0.5
Combined Digested	1.8 to 5.9	1.2 to 3.5	0.1 to 0.4

Source: P. Aarne Vesilind, "Treatment and Disposal of Wastewater Sludges", Ann Arbor Science Publishers, Inc., Ann Arbor, Michigan

8-3 SLUDGE THICKENING

a. Purpose and Function

Sludge thickening is a process whereby the solids content of a sludge is increased while the liquid content is decreased. The net result of thickening is a reduction in the volume of sludge to be stabilized (digested), dewatered or hauled away. Volume reductions in the amount of sludge to be handled can result in sizeable savings in costs and increased process efficiencies. Digesters, for example, are designed on the basis of solids detention, which means that a thickener would allow for a smaller digester. Similarly, digesters are intended to stabilize or reduce only the volatile solids in sludge. Consequently, by increasing the solids and reducing the liquid in a sludge, more solids can be placed in a digester which results in more efficient use of the digester volume.

As an example of how effective sludge thickening can be in volume reduction, 1,000 gallons of sludge containing 1% solids would occupy only 500 gallons when thickened to 2% solids and only 200 gallons when thickened to 5% solids. The two most common methods used to thicken wastewater sludges are gravity thickeners and dissolved air flotation.

b. <u>Gravity Thickeners</u>

Gravity thickeners usually resemble conventional circular clarifiers except that the floor has a steeper slope. The sludge usually enters in the middle of the thickener and the sludge solids settle into a sludge layer at the bottom. The settled sludge is gently agitated by a moving rake which dislodges gas bubbles, prevents bridging of the sludge solids, and keeps the thickened sludge moving toward the bottom hopper from where it is removed. Exhibit 8-1 depicts the details of a typical gravity thickener and Exhibit 8-2 shows an actual thickener in operation in Mississippi.

Thickeners can be used at various locations in wastewater facilities. Examples of sludges which are commonly placed in thickeners include:

1. Primary,
2. Secondary (Trickling Filter),
3. Secondary (Activated Sludge),
4. Combined (Primary and Secondary Activated Sludge), and
5. Combined (Primary and Secondary Trickling Filter).

Loading of thickeners is generally defined in units of pounds of suspended solids per day per square foot of surface area (lbs/day/ft^2). The concentrations to which thickeners can thicken sludge varies with the type sludge and loading rate. Table 8-3 shows some typical loading rates and thickened solids concentrations for common gravity thickeners.

c. <u>Dissolved Air Flotation Thickeners</u>

The process of dissolved air flotation (DAF) has been used successfully for thickening sludge. It generally is applicable for sludges which contain particles that tend to float rather than settle or which settle slowly and resist thickening by gravity. In most instances, dissolved air flotation has been employed to thicken secondary sludges from activated sludge processes or a combination of primary sludge and secondary activated sludge.

The process is based on using rising air bubbles to increase the buoyancy of solid particles and thereby cause them to float to the surface. At the surface, the flotation particles form a sludge blanket where the actual thickening occurs. The sludge blanket is typically eight (8) to twenty-four (24) inches thick. The buoyancy of the air-aided sludge particles forces the sludge blanket above the water surface and allows it to be removed with skimming blades or rakes. Exhibit 8-3 illustrates the details of a typical rectangular dissolved air flotation thickener. Exhibit 8-4 shows an actual DAF thickener in operation.

The dissolved air flotation process normally involves the introduction of air into the sludge through a revolving impeller or porous media. The bubbles produced by the injected air are attached to sludge particles, thus causing flotation and subsequent thickening at the surface. It is a common practice to add a chemical coagulant to improve the performance of flotation thickeners. The addition of the coagulants allow higher loading rates and increase the solids concentration which can be achieved in the sludge blanket.

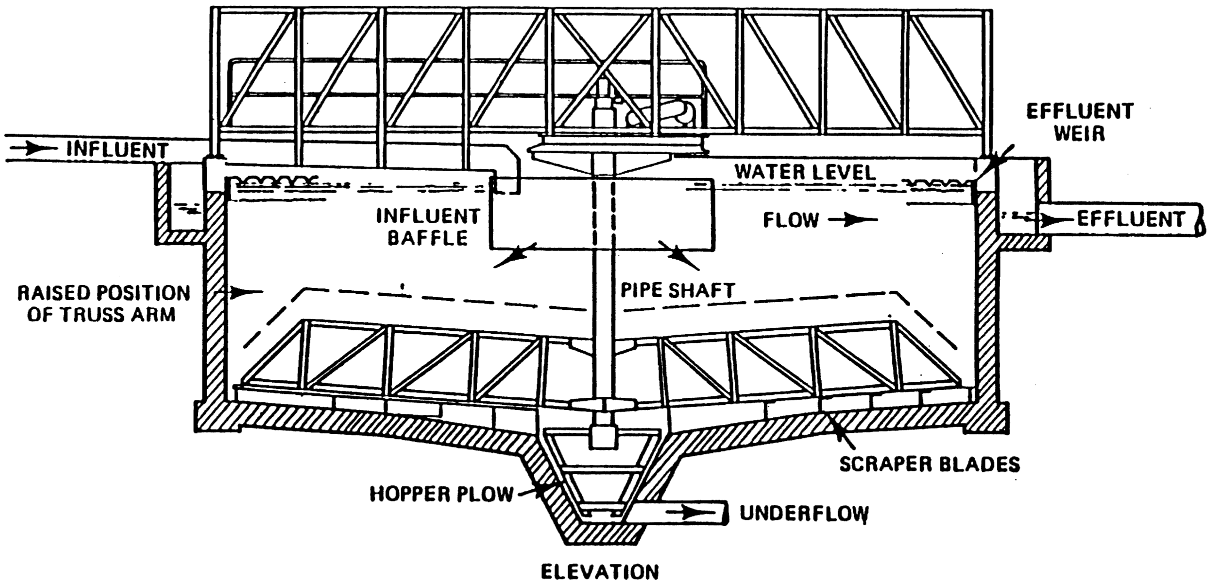


EXHIBIT 8-1

SECTIONAL VIEW OF TYPICAL GRAVITY THICKENER

Source: Process Design Manual for Sludge Treatment and Disposal, U.S. EPA, Technology Transfer

EXHIBIT 8-2

GRAVITY THICKENER

TABLE 8-3

TYPICAL LOADING RATES AND RESULTS OF GRAVITY THICKENERS

TYPE OF SLUDGE	(lbs/day/ft^2)	(% Solids)
Separate Sludge		
Primary	20 to 30	8 to 10
Secondary/Trickling Filter	8 to 10	7 to 9
Secondary/Activated Sludge	5 to 6	2.5 to 3
Combined Sludges		
Primary and Secondary/ Trickling Filters	10 to 12	7 to 9
Primary and Secondary/ Activated Sludge	6 to 10	5 to 8

Source: "Process Design Manual for Sludge Treatment and Disposal", U.S. EPA 625/1-74-006, Technology Transfer, October 1974.

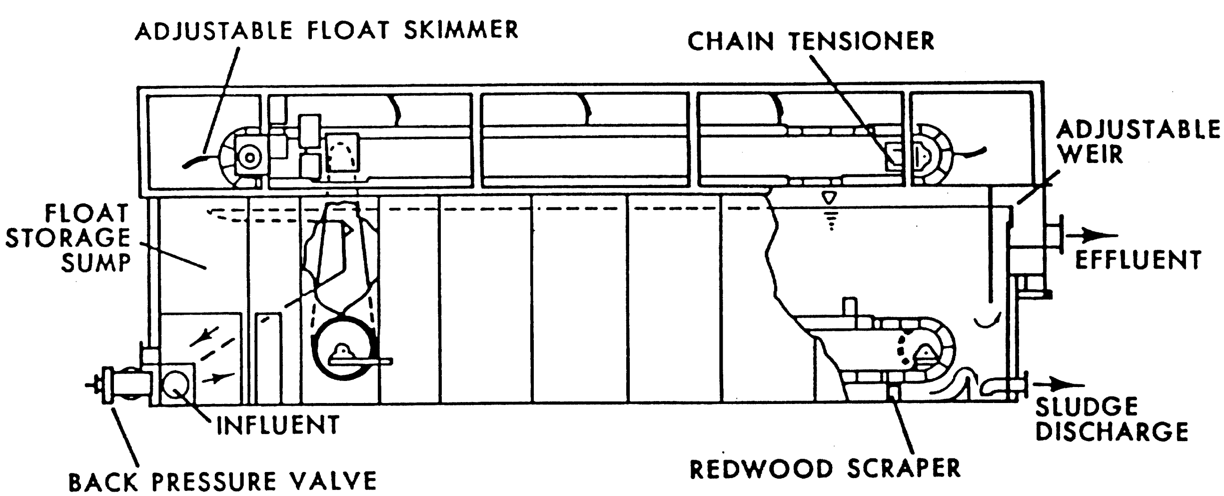


EXHIBIT 8-3

SECTIONAL VIEW OF TYPICAL DISSOLVED AIR FLOTATION THICKENER

Source: Process Design Manual for Sludge Treatment and Disposal U.S. EPA, Technology Transfer

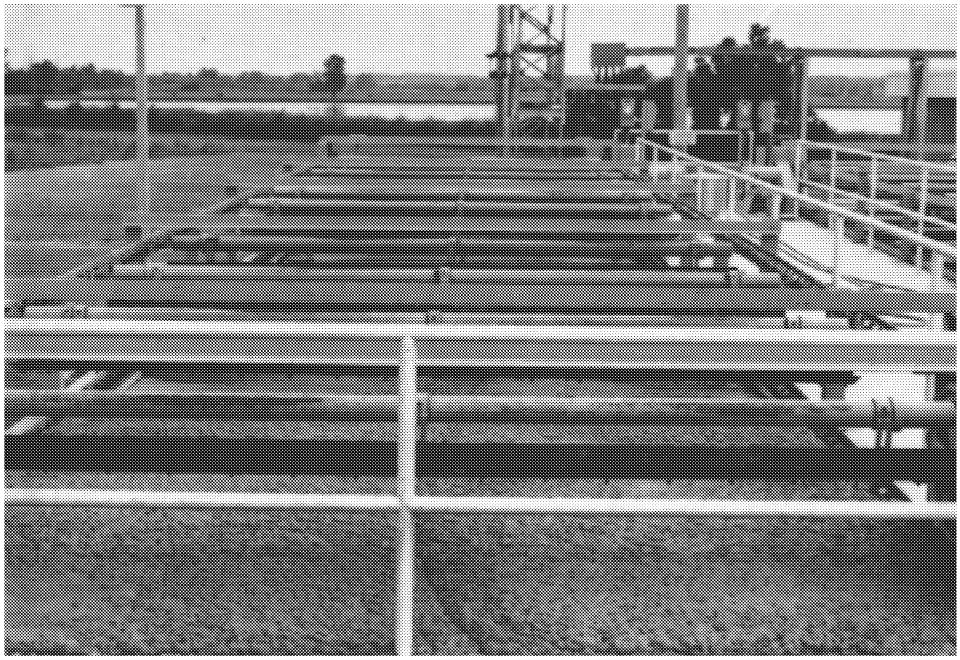


EXHIBIT 8-4

DISSOLVED AIR FLOTATION THICKENER

Performance of dissolved air flotation thickeners are based on the following factors:

1. Solids Loading - It is common to operate at suspended solids loadings of 2 to 4 pounds per hour per square foot of surface area (lbs/hour/ft^2).
2. Solids Concentration - A solids content in the surface sludge blanket of 4% to 6% solids can normally be achieved.
3. Hydraulic Loading - As a general rule, a maximum hydraulic loading of about 0.8 gallons per minute per square foot of surface area (GPM/ft^2) is allowed.

8-4 SLUDGE STABILIZATION

a. Purpose and Function

As previously discussed, wastewater sludges must be properly treated before they can be disposed of to the environment without causing harmful effects. Raw or untreated sludges normally contain organics and can produce obnoxious odors if disposed of without proper treatment. It is, therefore, necessary to treat sludges by stabilizing the organic or volatile content. The term "stabilization" is used to describe the various processes whereby the volatile content of sludge is reduced to a level where biological activity is minimal. By stabilizing a sludge, it can be more effectively handled and disposed of without creating harmful environmental effects or nuisance conditions.

Stabilization can be achieved through biological processes such as anaerobic and aerobic digestion or through chemical processes utilizing lime, chlorine, or oxygen.

b. Anaerobic Digestion

Anaerobic digestion is perhaps the oldest and most widely used method of sludge stabilization. The process, which is the same as exists in old septic tank systems, is a complex biochemical process in which several groups of anaerobic and facultative bacteria simultaneously assimilate and breakdown organic matter. Anaerobic digestion is mainly used to stabilize primary and secondary sludges, at trickling filter facilities, although it is not uncommon to see it used at activated sludge facilities. It can be generally described as a two-phase process as follows:

1. Acid forming bacteria convert organic matter to volatile organic acids. During this phase, there is very little change in the quantity of organic matter, although the pH is generally lowered by the formation of acids.
2. Gas forming bacteria convert the volatile organic acids to methane (CH_4) and carbon dioxide (CO_2). The relative amounts of gas produced are generally about 65%-70% methane (CH_4) and 30%-35% carbon dioxide (CO_2). The quantity of gas produced is normally about 11 to 12 cubic feet per pound of solids digested in a well operated system.

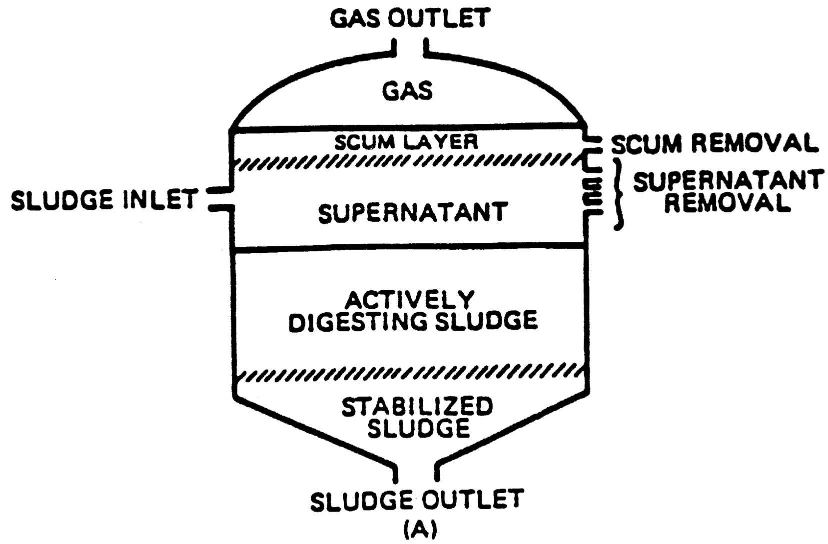
There are two (2) types of anaerobic digestion systems commonly used: standard (conventional) rate and high rate. Exhibit 8-5 illustrates the details and characteristics of both of these systems.

In a standard rate digester, which is probably the more widely used, three (3) distinct zones of decomposition develop. A scum layer is formed at the top and supernatant and sludge zones are created beneath it. The sludge zone has an upper layer where biological activity is high and a relatively stabilized bottom layer. The stabilized sludge is collected and withdrawn from the bottom of the digester. The supernatant is typically returned to the influent of the treatment plant. The quality of the supernatant should be monitored before returning to the treatment plant to avoid potential plant upsets.

A high-rate digester does not contain the decomposition layers found in standard-rate systems. Instead, the digester contents are in a mixed state. Usually, a post-digestion thickener is needed for the digested sludge from a high-rate system prior to dewatering. The mixing aspects of digesters offer better process control and prevent in-tank settling problems.

There are numerous factors which influent the operational performance of anaerobic digesters, regardless of whether it is a high-rate system or standard-rate system. The major factors can be summarized as follows:

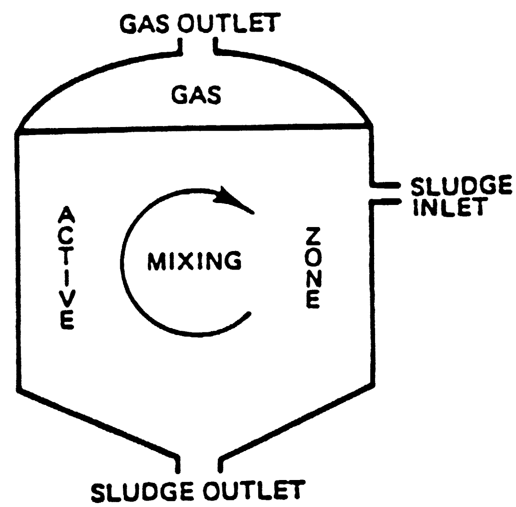
1. Bacteria - The acid forming bacteria are resistant to changes in their environment (temperature, pH, etc.). The gas formers are strictly anaerobic and extremely sensitive to changes in their environment. Factors such as pH, toxic wastes, detergents, alkalinity, ammonia, sulfides, and temperature can significantly effect gas forming bacteria.
2. Feed Rate - Digesters are usually fed intermittently. It is desirable for the sludge to be as concentrated as possible. A solids content of at least 4% to 8% is recommended.
3. Detention Time - Sufficient detention time obviously must be provided in order for the anaerobic processes to take place. The amount of detention required is dependent on temperature. As the temperature in the digester increases, the amount of detention time needed is reduced. Standard rate digesters typically utilize detention times of 30 to 60 days as compared to 10 to 15 days in high-rate systems.



(A)

STANDARD RATE DIGESTION

1. UNHEATED
2. DETENTION TIME 30 – 60 DAYS
3. LOADING 0.03 – 0.10 lb. VSS/cu. ft./day
4. INTERMITTENT FEEDING AND WITHDRAWAL
5. STRATIFICATION



(B)

HIGH RATE DIGESTION

1. HEATED TO 85° – 95° F
2. DETENTION TIME 15 DAYS OR LESS
3. LOADING 0.10 – 0.50 lb. VSS/cu. ft./day
4. CONTINUOUS OR INTERMITTENT FEEDING AND WITHDRAWAL
5. HOMOGENEITY

EXHIBIT 8-5

STANDARD RATE & HIGH RATE ANAEROBIC DIGESTERS

Source: "Process Design Manual for Sludge Treatment and Disposal," U.S. EPA, 625/1-74-006, Technology Transfer, October 1974

4. Temperature - Bacterial activity is directly controlled by the temperature maintained in a digester. Temperatures in the range of 85-100˚F (29-37˚C) are needed, with 95˚F (35˚C) being the optimum at which bacterial activity is most effective. A temperature change of 1 to 2 degrees can be sufficient to disturb the balance between acid and gas forming bacteria. Such an imbalance can cause an upset of the digester because the acid formers are able to respond more rapidly to changes in temperature than the gas formers. In cold weather climates, heating devices are needed to maintain desirable temperatures.

5. pH - Because gas forming bacteria are extremely sensitive to slight changes in pH, close control of this parameter is needed. It is generally acceptable to maintain the pH in a range of 6.8 to 7.2. During the gas production phase of digestion, a great quantity of carbon dioxide (CO_2) is produced which tends to lower the pH. However, when conditions are balanced, the pH is normally maintained by natural bicarbonate buffers. Problems often arise when sufficient buffers are not available which prevents the gas formers from converting the organic (volatile) acids to methane and carbon dioxide and results in a build-up of acids and drop in pH. When this happens an external source of alkalinity must be added.

6. Toxins - Toxic substances can easily and quickly upset a digester by destroying the bacteria. Substances which have been known to be toxic to digester bacteria include heavy metals, sulfides, and chlorinated hydrocarbons. Every effort should be made to monitor and control toxin content in sludge prior to placing it in a digester.

7. Volatile Solids Reduction - A 40% to 60% reduction in the amount of volatile solids is normally achieved.

Exhibit 8-6 shows selected anaerobic digesters presently in operation at Mississippi wastewater facilities.

c. <u>Aerobic Digestion</u>

Aerobic digestion involves the separate aeration of primary sludge and secondary sludge or a combination thereof from an activated sludge process. The process simply involves the biological oxidation of organic matter to cellular matter and the further oxidation of the cellular matter to digested sludge as illustrated below:

Organic Matter + $O_2 \xrightarrow{\text{Bacteria}}$ Cellular Matter + CO_2 + H_2O

Cellular Matter + $O_2 \xrightarrow{\text{Volatile Solids}}$ Digested Sludge + CO_2 + H_2O.

The second phase of the above illustration is called "endogenous respiration" and it can be described as the bacteria utilizing the cell tissue of other bacteria as a food source. The idea is to aerate the sludge for a sufficiently long period without introducing a fresh source of organic matter thereby forcing the bacteria into endogenous respiration where the only source of organics (food) is the cell tissue of other bacteria. Stabilization is normally not complete until the digester has operated at an extended period (15 to 20 days) in an endogenous stage. A properly operated aerobic digester will eliminate odors from the sludge, reduce the volatile solids content of the sludge, improve sludge dewatering characteristics, and leave a well-clarified supernatant. The supernatant is usually returned to the main treatment process. Exhibit 8-7 is a schematic diagram of an aerobic digestion system.

In appearance, an aerobic digester resembles the aeration basin of an activated sludge facility as can be seen in Exhibit 8-8, which shows some aerobic digesters at various wastewater treatment plants in Mississippi. The general advantages offered by aerobic digesters <u>as compared to anaerobic systems</u> include the following:

1. Relatively simple to operate,
2. Requires a small capital expenditure,
3. Does not generate significant odors,

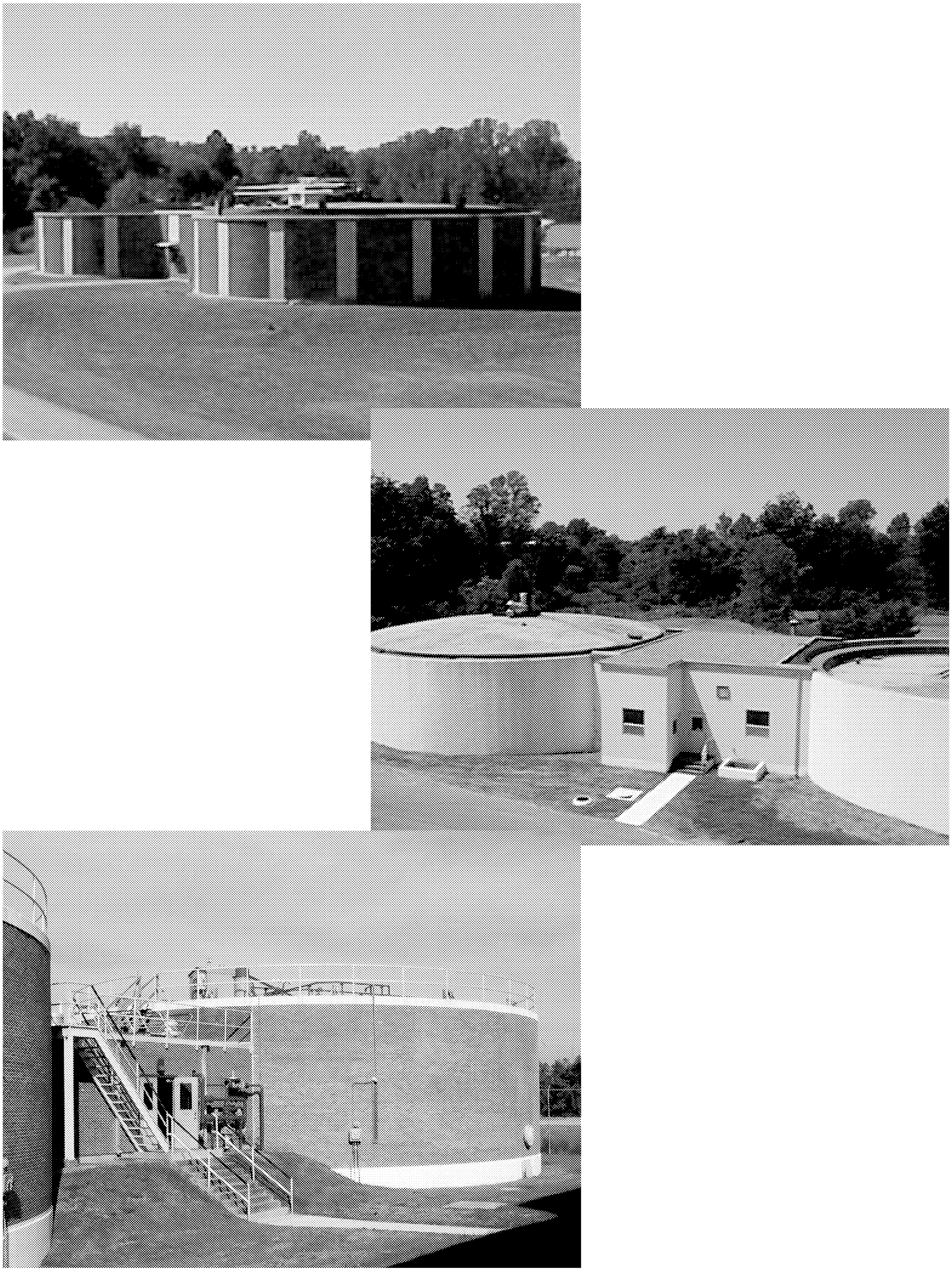


EXHIBIT 8-6

ANAEROBIC DIGESTERS

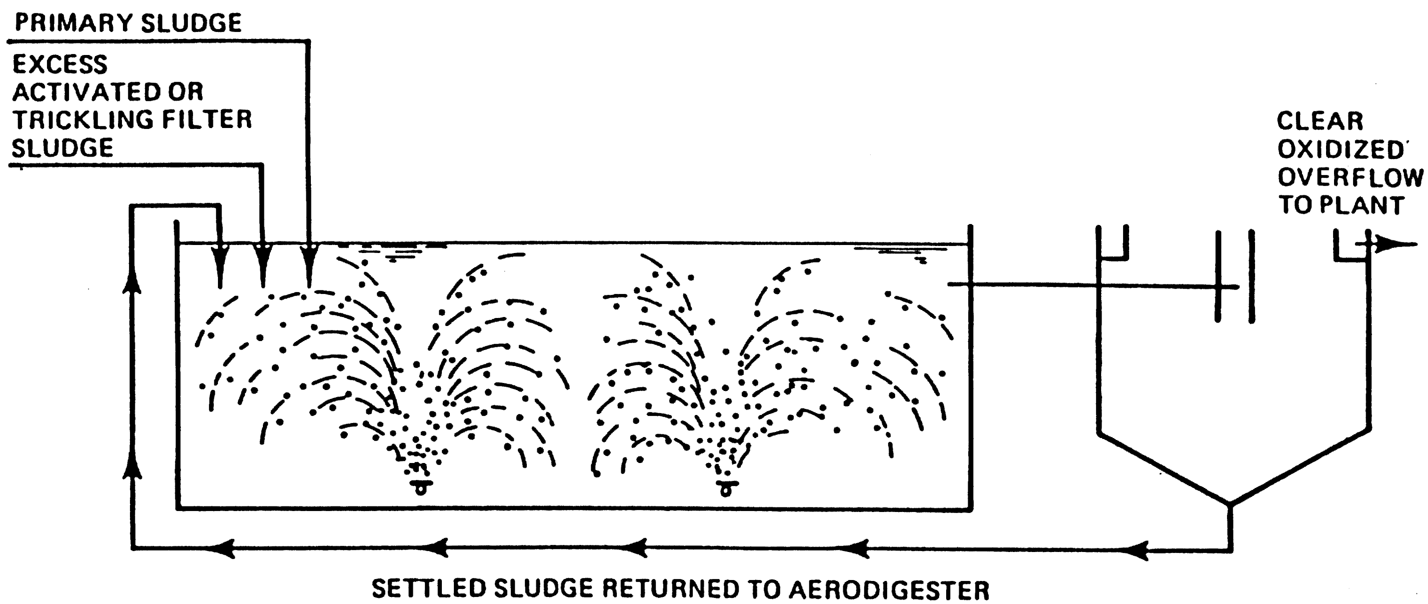
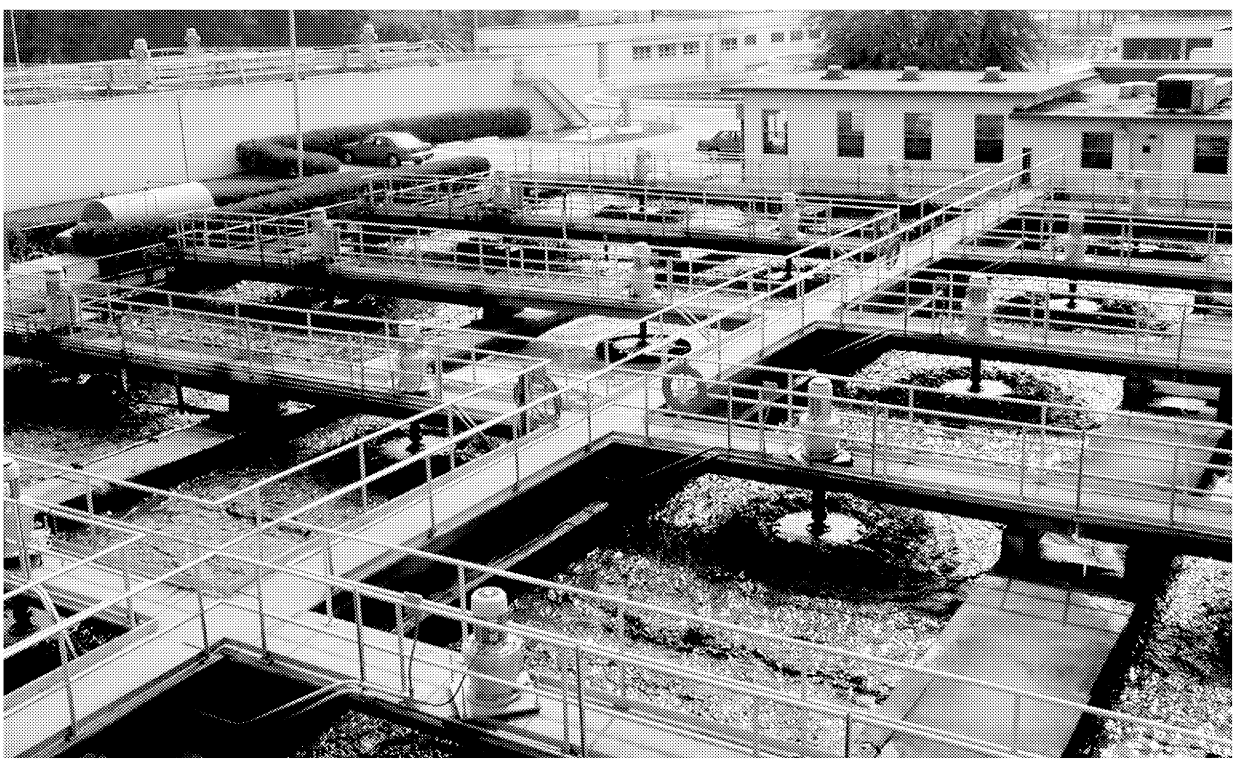


EXHIBIT 8-7

SCHEMATIC DIAGRAM OF TYPICAL AEROBIC DIGESTERS



AEROBIC DIGESTERS

EXHIBIT 8-8

4. Reduces pathogenic organisms to a low level,
5. Reduces the quantity of grease, and
6. Produces a supernatant, if clarified, that is low in BOD, solids, and phosphorus.

Operational procedures and criteria have not been established for aerobic digesters to the same extent as has been done for anaerobic systems. However, the following factors are known to influence and reflect the performance of aerobic digesters:

1. Oxygen Requirements - Using diffused aeration, about 20 to 35 cubic feet of air per minute per 1,000 cubic feet of digester volume is needed to stabilize secondary sludge. This figure increases to about 60 cubic feet per minute per 1,000 cubic feet for a combination of primary and secondary sludge. Dissolved oxygen concentration in a digester should be maintained at a minimum level of 1 to 2 mg/l.
2. Aeration Time (Detention) - As a general rule, 15 to 20 days detention time is typically required to achieve thorough stabilization.
3. Loading Rate - Loadings will typically vary from 0.1 to 0.2 pounds of volatile suspended solids per cubic feet per day.
4. Temperature - In cold weather, longer detention times may be required because biological activity decreases.
5. Volatile Solids Reduction - A 40% to 50% reduction in the amount of volatile solids is normally achieved.

d. Chemical Stabilization

In addition to biological stabilization of wastewater sludges through the processes of aerobic and anaerobic digestion, sludge can be effectively treated with the application of certain chemicals. The three (3) most common methods of chemical stabilization are chlorine oxidation, lime treatment, and oxygen stabilization. A brief description of each of these processes follows:

1. Chlorine Oxidation - This process was introduced by the BIF Corporation and is known commercially as the "Purifax" process. In the process, sludge is oxidized (stabilized) using very high dosages of chlorine. Dosages of about 2,000 mg/l are necessary. Sludge stabilized by this method generally requires chemical conditioning before it will dewater easily. Also, the stabilized sludge typically will have a low pH and a high concentration of chloramines, which sometimes make final disposal into the environment difficult.
2. Lime Treatment - In this process lime is added in sufficient quantities to maintain a pH between 11.0 and 11.5 which results in the destruction of most biological life. This procedure not only stabilizes the sludge, but it also destroys pathogenic bacteria. Lime stabilized sludges dewater easily on drying beds with virtually no odor problems.
3. Oxygen Stabilization - This process uses oxygen to stabilize sludge under temperature and pressure. The commercially available "Zimpro" process is the best known oxygen stabilization method. This process places the sludge under pressures ranging from 150 to 3,000 psi. Steam is used to raise the temperature which will sustain oxidation reactions. The sludges stabilized by this method are sterile and easily dewatered.

8-5 SLUDGE CONDITIONING

Once wastewater sludges have been treated or stabilized, their subsequent handling and disposal often can be improved by prior "conditioning" of the sludge. The purpose of sludge conditioning is usually to improve dewatering characteristics. Hence, the term "sludge conditioning" is used to describe the treatment of sludge to facilitate dewatering.

The most widely used methods of conditioning sludge are listed and described as follows:

1. Chemical Conditioning - This method involves the addition of chemicals that aid in separating the sludge particles from water. Inorganic chemical coagulants such as ferric chloride and aluminum sulfate are used. In recent years, organic chemicals or polymers have been used to achieve the same results.
2. Elutriation - This method simply involves washing sludges to remove constituents that interfere with dewatering operations. Its use is mainly confined to anaerobically digested sludges. In most instances, the process requires about twice as much wash water as there is sludge. The wash water is normally returned to the influent of the treatment plant and the wasted sludge routed to drying beds or other dewatering facilities. A common problem that occurs with elutriation systems is that an excess amount of solid material can easily be returned with the wash water and eventually lead to a build-up within the plant.
3. Heat Treatment - This method involves routing sludge through a heat exchanger at temperatures of about 380˚F for a duration of 20 to 30 minutes. It is common to pump the sludge through the exchanger under pressure of about 270 psi. The head and pressure destroy the bacterial cells in the sludge and allow the water bound inside the cells to escape.
4. Ash Addition - This process has been used successfully to improve the performance of vacuum filters and filter presses for dewatering. Usually, fly ash in the amount of one-half (½) the weight of the sludge being conditioned will yield the desired results. The ash will provide improved cake release from belt-type vacuum filters and filter presses.

8-6 SLUDGE DEWATERING

a. Function and Purpose

Sludge dewatering, as the name implies, simply involves the removal of water from sludges so as to change the physical form of the sludge from a liquid to a damp or dry solid. By changing the form to that of a solid, final disposal of the sludge is much easier and less expensive to achieve. Dewatering of wastewater sludges can be achieved by a number of proven methods which include the following:

1. Drying Beds,
2. Vacuum Filters,
3. Belt Filter Presses,
4. Lagoons, and
5. Centrifuges.

Each of these methods can and have been successfully utilized. The selection of a method is inherently included in the design of a treatment facility and is influenced by economics and the quantity/quality of the sludges involved.

b. Drying Beds

Drying beds are perhaps the oldest and most common methods used for dewatering wastewater sludges. Beds are constructed of layer(s) of sand over gravel and underdrains surrounded by shallow-walls usually constructed of concrete. Exhibit 8-9 shows the details of a typical sand drying bed. Exhibit 8-10 shows some drying beds in use at various wastewater treatment facilities in Mississippi.

The removal of water from sludge placed on a drying bed actually is a two-step process. The first step involves the drainage of water from the sludge into the sand/gravel bed and underdrains. This initial phase generally requires a few days until the sand/gravel bed is clogged with fine particles and/or until all the free water has drained away. Further dewatering during the second step is achieved by evaporation.

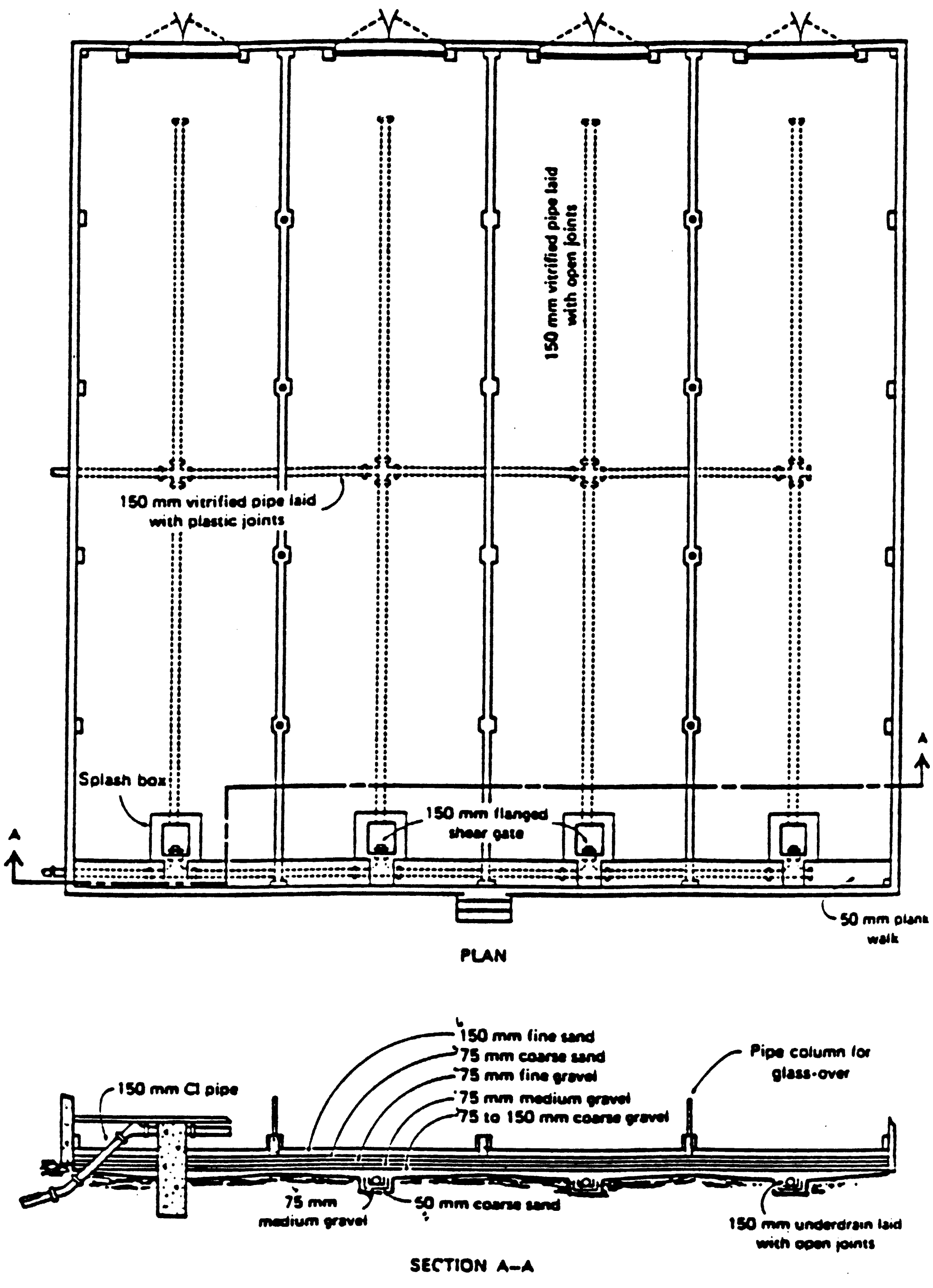


EXHIBIT 8-9

PLAN & SECTIONAL VIEW OF TYPICAL SLUDGE DRYING BED

Source: Metcalf and Eddy, Inc., Wastewater Engineering, McGraw-Hill, 1979

EXHIBIT 8-10

SLUDGE DRYING BEDS

Beds are usually sized to accommodate the expected load to a treatment plant in terms of the number of persons which the plant has the capacity to serve. Table 8-4 lists typical area requirements for various types of sludges. The depth of sludge placed on beds varies with sludge, weather conditions, and individual operational techniques, but in most cases a depth of 9 to 15 inches is applied. Complete dewatering may vary from several days to a few weeks depending largely on the weather and condition of the sludge. Exhibit 8-11 shows what a well dewatered sludge looks like after it has been on beds for sufficient drying time and is ready for removal and final disposal.

The water drained from the sludge into the bed should be collected in underdrains and routed back to the main treatment process. The dried sludge is removed from the bed surface and disposed of by various final disposal measures which include landfilling and land spreading.

c. <u>Vacuum Filtration</u>

Vacuum filters have been in use for several years for the purpose of dewatering wastewater sludges. The most common type of vacuum filter is a rotary drum. Exhibit 8-12 shows a sectional view of a typical rotary drum filter. The drum is a cylinder which rotates in a partially submerged vat or pan of sludge, which usually has been conditioned. The drum is covered with a permeable fabric or similar material. A vacuum is drawn inside the drum which draws or sucks the water from the sludge through the fabric into vacuum lines inside the drum. The filtrate is then pumped from inside the drum back to the main treatment process. The sludge which remains on the fabric is scraped off as filter cake and disposed of.

Exhibit 8-13 shows a vacuum filter in operation at a treatment facility in Mississippi.

d. <u>Belt Filter Presses</u>

Belt filter presses consist of sludge being fed between two filter belts and thence being squeezed by the belts. This squeezing action forces or “presses” the water from the sludge. The water squeezed from the sludge is returned to the main treatment process and the sludge which remains on the belt is scraped off and collected as filter cake for final disposal. Exhibit 8-14 shows belt filter presses in operation at treatment facilities in Mississippi.

e. <u>Lagoons</u>

Dewatering or drying lagoons are very similar to drying beds in the sense that sludge is placed in the lagoons, allowed to dry and thence removed. In certain instances, lagoons have been used as a permanent disposal site by never removing the sludge. Odor problems with lagoons can be greater than those encountered with drying beds because the sludge in a lagoon retains more water for a longer period of time. Lagoons should be used only where the soil is reasonably porous and sufficiently above the maximum groundwater table. The lagoon should be diked to prevent surface water from entering. Most drying lagoons are loaded at a rate of 2.2 to 2.4 pounds of sludge per year per cubic foot of lagoon volume. Lagoon depths should be limited to about 2 feet.

f. <u>Centrifuges</u>

Centrifuges have long been employed as a dewatering device for wastewater sludges. A centrifuge uses centrifugal force to separate the solid matter and water in sludge. A continuous bowl type centrifuge, as illustrated in Exhibit 8-15 is probably the most common centrifuge device. The major components of such a device are the rotating

TABLE 8-4

AREA REQUIREMENTS FOR DRYING BEDS

TYPE OF DIGESTED SLUDGE	AREA REQUIRED (SQ. FT./CAPITA)
Primary	1.0 to 1.5
Primary plus Secondary/Trickling Filter	1.25 to 1.75
Primary plus Secondary/Activated Sludge	1.75 to 2.5
Primary plus Chemical	2.0 to 2.5

Source: P. Aarne Vesilind, "Treatment and Disposal of Wastewater Sludges," Ann Arbor Science Publishers, Inc., Ann Arbor, Michigan, 1975.

EXHIBIT 8-11

DRIED/DEWATERED SLUDGE

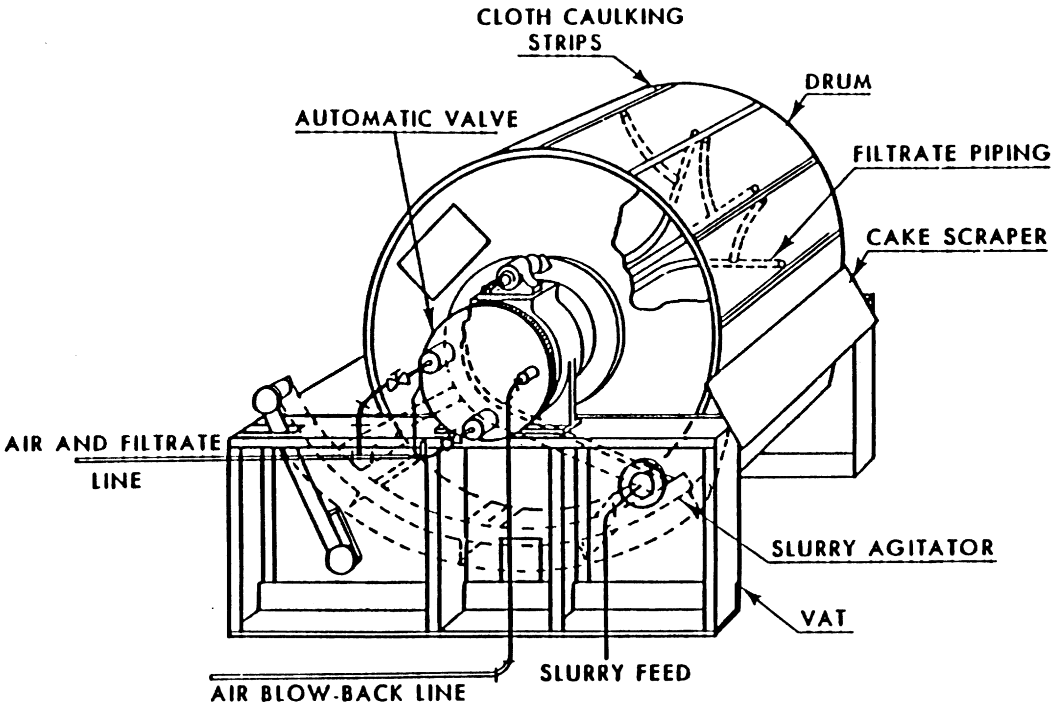


EXHIBIT 8-12

TYPICAL ROTARY DRUM VACUUM FILTER

Source: Process Design Manual for Sludge Treatment & Disposal U.S. EPA, Technology Transfer

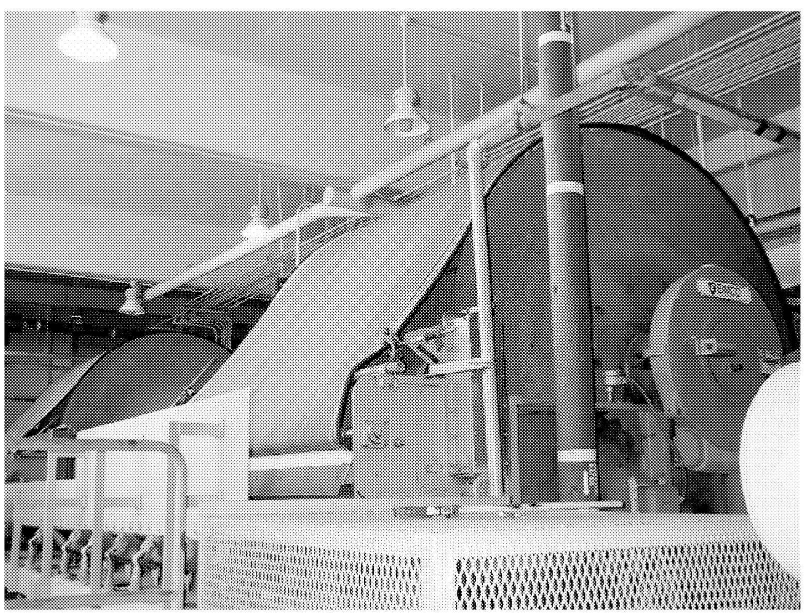
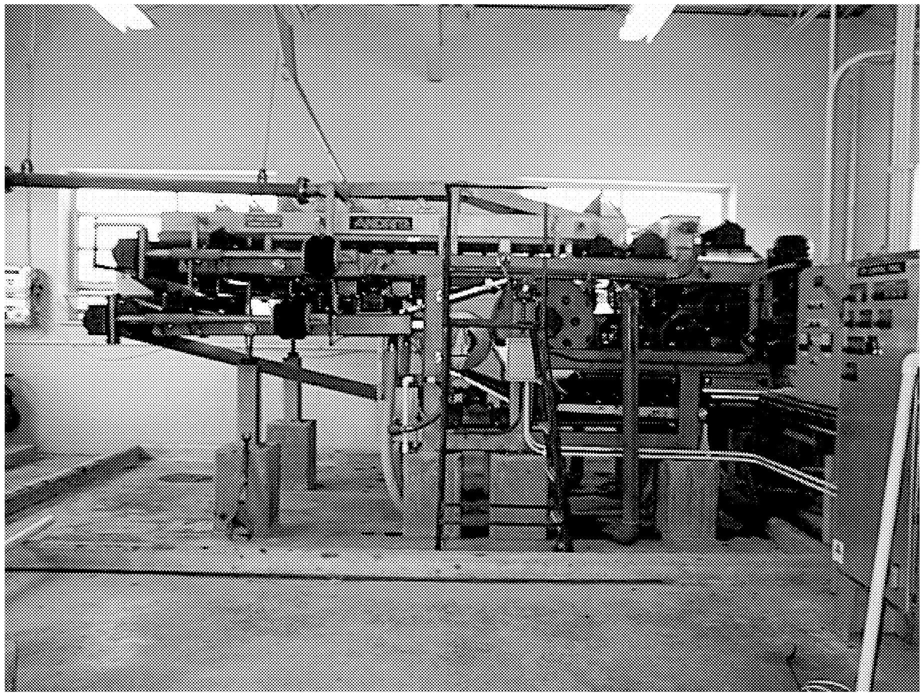


EXHIBIT 8-13

VACUUM FILTER



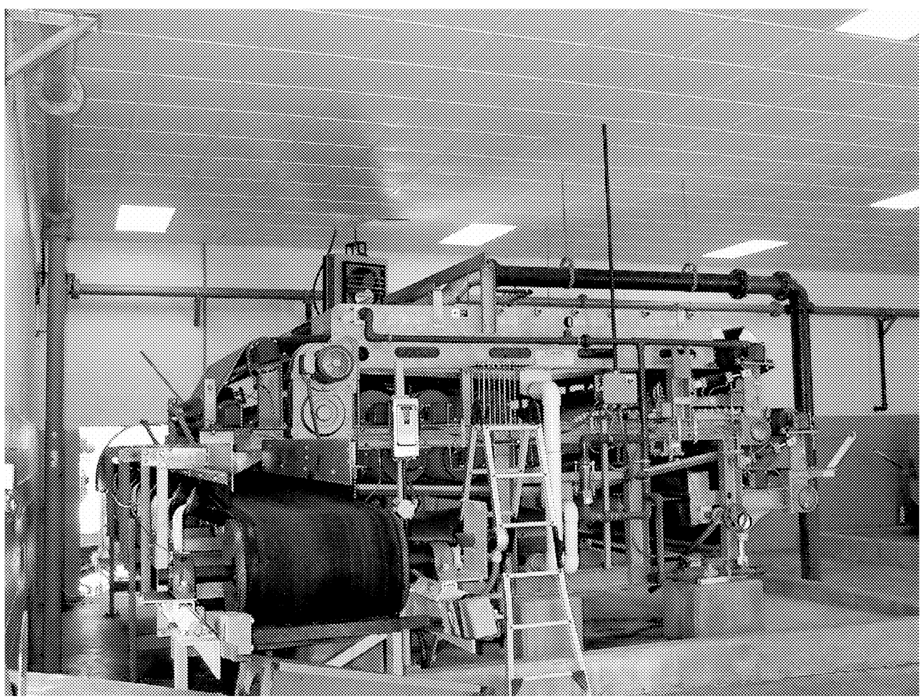


EXHIBIT 8-14

BELT FILTER PRESSES

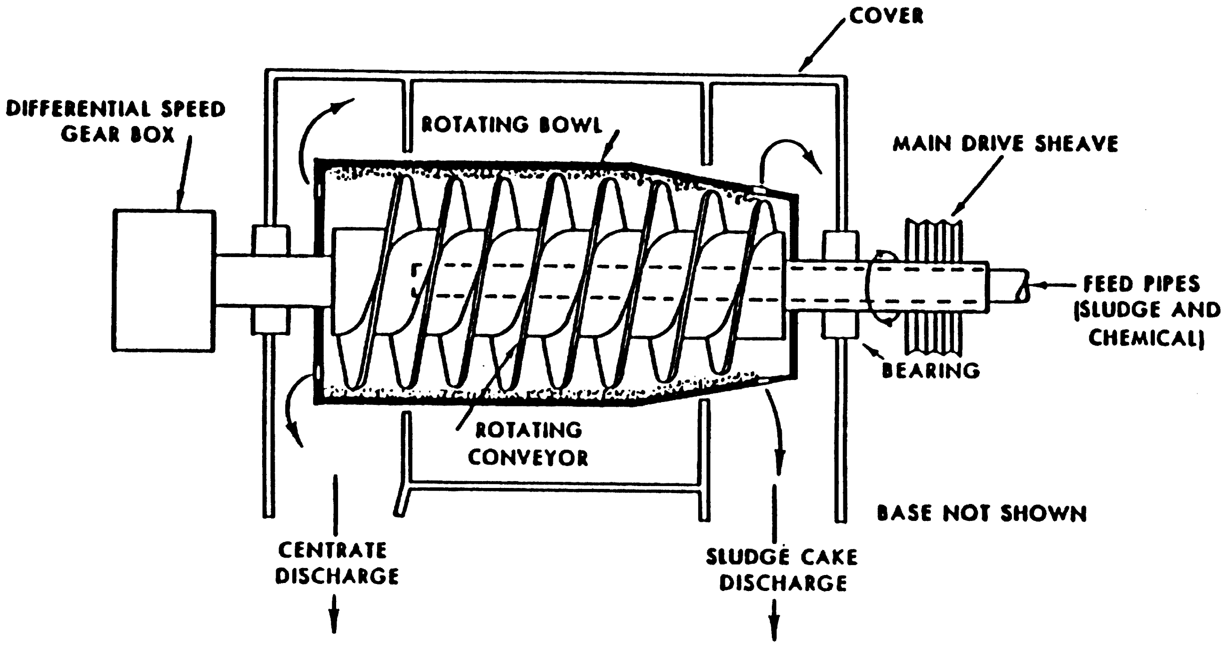


EXHIBIT 8-15

CONTINUOUS SOLID BOWL CENTRIFUGE

Source: Process Design Manual for Treatment and Disposal of Sludge U.S., EPA, Technology Transfer

bowl and a conveyor discharge for removal of the separated solids. As the bowl rotates, centrifugal force causes the solids to separate from the sludge. As the solids are collected in the bowl, they are picked up by the conveyor and continuously removed for final disposal. The water separated from the solids is returned back to the main treatment process.

8-7 FINAL DISPOSAL METHODS

Once sludge has been subjected to whatever stabilization, conditioning, and dewatering processes are required, it must be finally disposed of in an environmentally-safe manner. Final disposal can be achieved on the land, in the sea, or in the air. In due time when technology makes it more cost effective, outer space will likely offer an additional disposal environment. In terms of practicality and economics, the land is the most attractive and the most commonly-used environment for final disposal. Although utilized by a few entities, ocean disposal is not fully condoned by the U.S. Environmental Protection Agency; and even when such practice is permitted, location near a gulf or ocean is virtually required in order for it to be cost-effective. Utilization of the air for final disposal through such methods as incineration is, in reality, only temporary since ash and other emissions ultimately fall out and settle to the earth.

Whatever environment and methodology are utilized for final sludge disposal, the following basic needs should be fulfilled:

1. Pollution of air and water should not occur;
2. Cost-effective/economical practices should be used;
3. Organic matter should be conserved and utilized as beneficially as can reasonably be achieved; and
4. A permanent solution to the problem of sludge disposal should be provided.

The more widely used methods of final sludge disposal include the following:

1. Landfilling - As the name implies, landfilling sludge involves depositing stabilized and dewatered sludge in a sanitary landfill where it is subsequently covered with soil. Once a very common practice, landfilling has declined somewhat as an alternative for final disposal due to the fact that the availability of landfills has been reduced significantly. Due to restrictions placed on the management and construction of landfills to prevent groundwater contamination, many facilities have been closed. Components required for a landfill operation to be approved, such as monitoring wells, leachate collection, and liners have resulted in higher operation costs for landfill users. Thus, the cost of landfilling sludge and other materials is now more expensive and, consequently, less attractive.

2. Landspreading - Placing sludge on agricultural lands or other dedicated tracts of land is a popular method of final disposal in many areas. In the case of agricultural land, sludge represents a source of nutrients and acts as a soil conditioner. Municipal wastewater sludge typically contains significant amounts of nitrogen and phosphorus. Nitrogen may exist in any one of four forms - organic nitrogen, ammonia, nitrite, or nitrate. Organic nitrogen must be converted to one of the inorganic forms by soil bacteria before it can be utilized as a plant nutrient, but the other three forms are readily available as nutrients. Ultimately, it is estimated that approximately eighty percent (80%) of all nitrogen in municipal sludge is available for plant nutrients.

   Phosphorus content in municipal sludge is usually about the same as commercial inorganic fertilizers and the plant utilization rate is typically in the range of forty percent (40%) to eighty percent (80%). It is common practice to utilize nitrogen loading as the basis on which to determine sludge application rates on agricultural land. As a general rule, the rate of application is equal to the nitrogen uptake rate of the crop being grown. The approved use of municipal sludge for agricultural purposes is primarily confined to non-edible crops. Although current regulations allow use of sludges on food crops with certain restrictions depending on the classification of the sludge, widespread use for such purposes has not yet been condoned by regulatory agencies.

   Landspreading is often practiced on non-agricultural lands which can be eliminated from public use. For example, sludge is sometimes spread within the confines of a wastewater treatment facility where sufficient unused acreage is available. Non-agricultural landspreading of sludge typically serves the purpose of a soil filler or conditioner.

   In localized or smaller landspreading operations, dewatered sludge is usually applied. Landspreading on large tracts for agricultural purposes is often achieved by spreading wet sludge and mixing it in the soil. Exhibit 8-16 shows a sludge-spreading vehicle commonly used for such disposal. In general, landspreading can be achieved with stabilized wet sludge as well as with dewatered sludge from vacuum filters, drying beds, centrifuges, lagoons, and filter presses.

3. Lagooning - Where ample land is available, lagoons are often utilized for permanent storage (disposal) of sludge. Such practice is common in communities which have replaced wastewater lagoons with activated sludge or trickling filter systems. Because the old lagoon usually has ample volume, digested sludge from activated sludge or trickling filter systems can be disposed of permanently therein. Sludge disposal lagoons have specific capacities which limit the volume of sludge which can be placed therein. Old wastewater lagoons which are converted to sludge disposal lagoons typically have liners or impervious clay bottoms which prevent seepage into underlying groundwater aquifers. New lagoons constructed for such purposes should also be properly lined to safeguard against groundwater contamination.

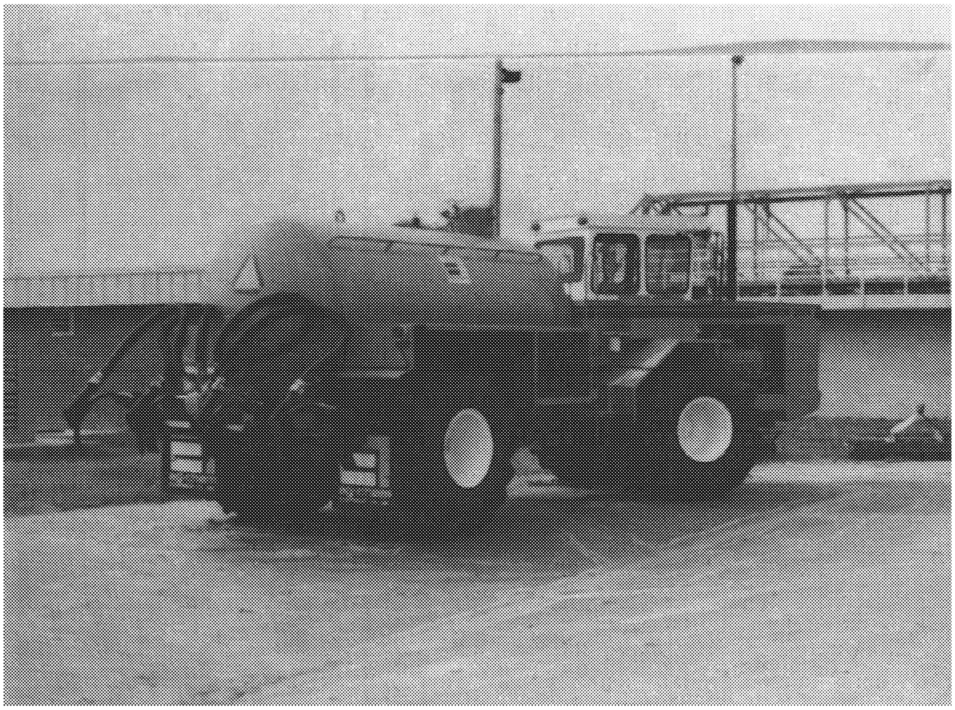


EXHIBIT 8-16

VEHICLE FOR LAND SPREADING OF WET SLUDGE

4. Land Farming - Land farming involves placing sludge on an area for the sole purpose of utilizing soil bacteria to assimilate sludge solids. Usually, land used for such purposes is not highly valued and is remotely located where the potential for nuisance conditions, health problems, or other environmental concerns is minimal. Sludge disposed of in this manner can often be sprayed on land without being dewatered.

5. Deep Well Injection - Injection of wet sludge into deep wells for permanent disposal below ground has been used successfully in certain instances. This method is more common where deep wells are already available (such as old oil fields). Due to high costs, it is not a common practice when new injection wells must be constructed. Where deep wells are used, extreme care must be taken not to contaminate a groundwater aquifer. Once the material has been injected into the ground, it is "there", so to speak, and little can be done to remove it; hence, the possible adverse effect of injection wells is a very serious matter which demands competent evaluation before being used.

6. Ocean Disposal - If a municipality or other entity is located in close proximity to a gulf or ocean, utilization of the marine environment for final disposal of sludge is a possibility. However, such practice is typically not condoned or encouraged by regulatory agencies. The use of ocean disposal is not considered to be a reasonable alternative in view of increasing regulatory restrictions.

7. Incineration - Although incineration of dewatered sludge has been and continues to be utilized as a means of final disposal, the practice is not deemed to be cost effective in most cases. In addition, the

ash and other products emitted from the incinerators ultimately fall-out from the atmosphere and settle to earth which makes the process temporary and creates other environmental concerns.

8. Contract Disposal - The use of contracted services to dispose of sludge is mistakenly often categorized as a final disposal alternative. Such practice merely transfers the problem to other persons and another location. However, from an economics perspective, it is often the most advantageous manner in which to deal with sludge disposal. Due to increased governmental restrictions, disposal services are becoming more readily available and more economically competitive. In smaller communities, contract disposal often provides the most attractive combination of cost, convenience, and dependability.

Regardless of the method of disposal, sludge must first be collected and appropriately loaded for transfer to the final disposal site. At smaller facilities, collection and loading is often achieved manually. Exhibit 8-17 shows dewatered sludge being manually removed from a drying bed and loaded into wheelbarrows for local disposal. Larger facilities frequently have conveyor belts or tractors to collect and transfer dewatered sludge to trucks for hauling to the final disposal site. Exhibit 8-18 shows some removal/loading facilities at selected wastewater treatment facilities in Mississippi.

EXHIBIT 8-17

MANUAL REMOVAL OF SLUDGE FROM DRYING BEDS

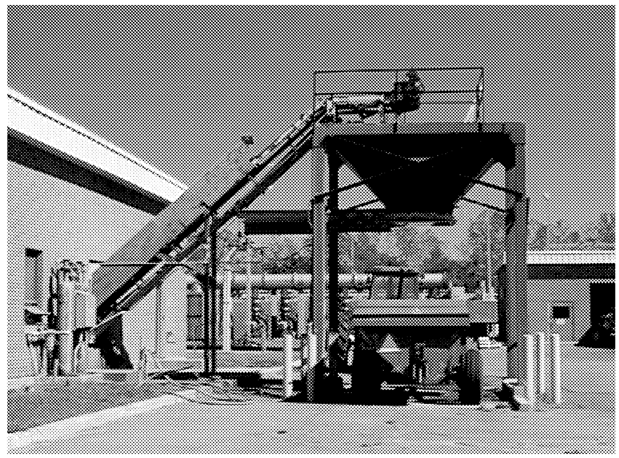


EXHIBIT 8-18

MECHANIZED REMOVAL/LOADING OF SLUDGE

CHAPTER 9

FLOW MEASUREMENT

* * * * *

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CHAPTER 9

FLOW MEASUREMENT

9-1 HISTORICAL BACKGROUND

The need to measure the rates at which liquids flow has been recognized since the beginning of civilization. More than 3,000 years ago, the Egyptians developed methods for measuring the stage of the Nile River to help predict floods. Later in 52 A.D., the first attempt to measure volume of water flow was made by a Roman water commissioner named Sextus Julius Frontius. Frontius' method involved measuring cross-sectional areas of spouts through which water was discharged and then making calculations of the volume based on the areas. His attempts were not successful because he ignored the velocity at which the water flowed from the spouts - a fact we have since learned must be taken into account. The Romans continued to struggle with measuring water flow through aqueducts and channels. Their struggles eventually led to principles of flow measurement that we know today.

It was not until the 17th and 18th centuries that the theories and concepts of liquid flow measurement on which most modern practices are based were developed. Most of the basic research and developments were accomplished by such men as Torricelli, Pitot, Waltman, and Venturi. Many of our modern flow-measuring devices bear the names of these early technicians. As general technology and science made great advances into the 19th and 20th centuries, comparable advances were made in liquid flow-measuring techniques. Even today, with the advent of space-age technology, advances in flow-measuring instrumentation continue to be made, although the basic principles on which measurements and calculations are made remain the same as developed by the early Egyptians and Romans. Today's technology has resulted in ways to more accurately measure, compute, and record liquid flows. The wastewater field has benefited from these advances as much, if not more, than any other field.

9-2 REASONS FOR MEASURING FLOWS

Simply and accurately stated, the measurement of flow at a wastewater treatment facility is absolutely essential to the proper operation and management of the facility. The reasons for this can be summarized as follows:

1. Flow is a necessary factor in the computation of many operational parameters discussed elsewhere in this manual such as F/M ratio, sludge age, return sludge rate, recirculation ratio, sludge withdrawal rate, chlorine feed rates, etc.
2. Flow must be monitored for compliance with Federal and State regulatory permits.
3. Flow is a vital standard by which the total load to a treatment facility, as well as the facility's reserve capacity, is measured.
4. Flow is necessary to determine and evaluate the results of conservation and quality control efforts.
5. Flow is an indicator of conditions which exist or can be expected at a wastewater treatment facility and is often the basis for establishing specific operational procedures.
6. Flow is a basis for establishing costs and levying charges to users of a sewer system and wastewater treatment facility.

Accurate flow measurement data combined with reliable laboratory test results provide the basis on which sound operational procedures are established at a treatment facility.

9-3 WEIRS

a. General Information

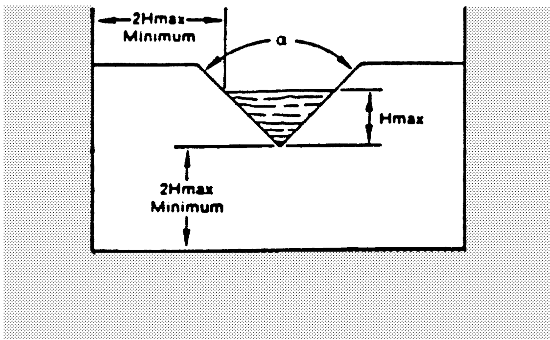
Weirs are the simplest and most common devices used to measure flow in open channels. They are also the least expensive to construct and operate. A weir can be defined as an obstruction built across an open channel with a specially shaped opening or "notch" over which the liquid flows. The edge or surface over which the liquid flows is called the "crest" of the weir. This surface is usually constructed with a sharp upstream edge so that the liquid tends to "spring" clear of the crest as it flows over. It is necessary that the crest be placed high enough to allow the liquid to be discharged freely into the atmosphere.

The rate of flow over a weir's crest can be computed by measuring the vertical distance from the crest of the weir to the water surface in the pool upstream from the crest. This depth of water is called the "head" on the weir and should be measured upstream of the weir at a distance equal to at least four times the head.

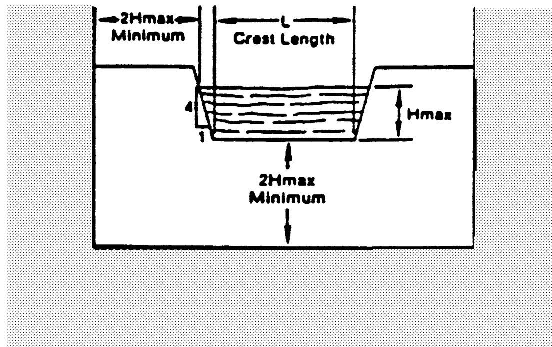
Weirs are usually classified according to the shape of the notch. The basic types of notches utilized in measuring wastewater flows are rectangular, trapezoidal, and triangular or "v-notch." These basic types are illustrated in Exhibit 9-1.

Although weirs are simple and inexpensive to construct and convenient to use, certain conditions must exist before accurate flow measurements can be made. For example, weirs are not suitable for flat-sloped channels where head loss must be considered. Also, weirs are not suitable for water carrying excessive solid materials or silt which will settle and build up deposits in the approach channel upstream of the weir. To assure accurate flow measurement with any type weir, the following general requirements should be met:

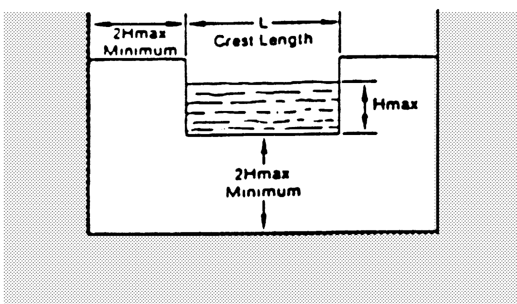
1. A weir should be constructed of a thin plate (⅛ to ¼ inch thick). The upstream edge of the crest must be sharp.
2. The upstream face of a weir should be smooth and perpendicular to the axis of the channel in both horizontal and vertical directions. The crest should be exactly level to insure a uniform depth of flow.
3. The connection of a weir to its channel should be watertight.
4. The length of the weir crest or the notch angle must be accurately determined.
5. The height of the weir from the bottom of the channel to the crest should be at least two (2) times the maximum expected head to lower the approach velocity. In no case should this distance be less than one (1) foot.
6. The upstream approach section to a weir should be straight for a distance of at least twenty (20) times the maximum expected head and have little or no slope.
7. The crest of a weir must be set higher than the maximum downstream water surface elevation to assure that free flow conditions will exist.
8. The device (flow meter) for measuring head on a weir should be placed upstream at a distance of at least four (4) times the maximum expected head. The device should be located in an undisturbed section of the channel or in a stilling well. The zero point of the head measuring device must be set exactly at the same elevation of the weir crest.
9. The crest of a weir must be kept clean and the upstream side of the weir plate should be periodically cleaned to remove accumulated deposits.
10. The type and size of a weir should be selected only after thorough study to determine the expected range of flow rates.



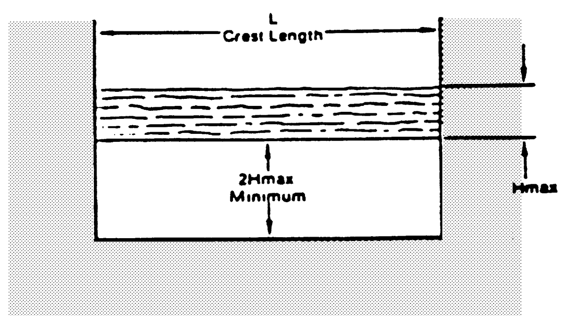
TRIANGULAR (V-NOTCH)
WEIR



TRAPEZOIDAL (CIPOLETTI)
WEIR



RECTANGULAR WEIR
WITH END CONTRACTIONS



RECTANGULAR WEIR
WITHOUT END CONTRACTIONS

EXHIBIT 9-1

BASIC TYPES OF WEIRS

Source: ISCO Open Channel Flow Measurement Handbook Instrumentation Specialties Co.; Lincoln, Nebraska

b. Triangular (V-Notch) Weirs

A triangular or “v-notch” weir consists of an angular notch cut into a weir plate (See Exhibit 9-1). The angle of the notch most commonly used is 90˚, although angles of 60˚, 45˚, 30˚, and 22½˚ are also used.

V-notch weirs are accurate flow measuring devices particularly suited for low flows. The general flow range in which accuracy is greatest is 0.65 to 6.5 million gallons/day (MGD). In general, it is recommended that the head maintained on a v-notch weir be at least 0.2 feet and not greater than 2.0 feet to assure accuracy. Table 9-1 lists the minimum and maximum recommended flow rates for v-notch weirs. Discharge tables for 90˚ and 60˚ v-notch weirs are presented in Tables 9-2 and 9-3 respectively.

c. Rectangular Weirs

A rectangular weir consists of a rectangle cut into a weir plate (See Exhibit 9-1). There are two basic kinds of rectangular weirs. The first is constructed with end contractions which consists of a rectangular notch cut into a weir plate in the flow channel. This configuration produces a box-like opening which reduces or “contracts” the width of flow from the full channel to the rectangular opening. The horizontal distances from the end of the weir crest to the sidewalls of the channel are called the “end contractions.” It is important that the length of the end contractions be at least twice the maximum head expected on the weir so that a free and unconstrained lateral approach to the crest will be provided.

The second type of rectangular weir is constructed without end contractions. In this type weir, the crest extends all the way across the channel with the sidewalls of the channel serving as sides of the weir. Flow through this kind of weir is sometimes called “suppressed” flow.

A crest length of at least one (1) foot should be used when constructing a rectangular weir because a v-notch weir can provide more accurate measurements than rectangular weirs with crests less than one (1) foot. Although it is not necessary, it has become common practice to construct rectangular weirs with crest lengths increasing in six inch increments up to three (3) feet and then in one (1) foot increments thereafter. Theoretically, there is no limit to the length of crest that may be used. However, crests of six (6) to eight (8) feet are usually the maximum lengths utilized due to economic considerations.

Rectangular weirs are accurate flow measuring devices suited to handle higher flows which exceed the capacities of v-notch weirs. As with v-notch weirs, it is generally recommended that a minimum head of 0.2 feet be maintained on a rectangular weir. Also, it is commonly accepted practice to limit the maximum head on a rectangular weir to no more than one-half the crest length. Table 9-4 lists the minimum and maximum recommended flows for rectangular weirs of various crest lengths. Discharge tables for both types of rectangular weirs with crest lengths up to three (3) feet are presented in Tables 9-5 and 9-6.

TABLE 9-1

RECOMMENDED FLOW RATES FOR V-NOTCH WEIRS

V-Notch Angle	Minimum Head, Ft.	Minimum Flow Rate* CFS	Minimum Flow Rate* MGD	Maximum Head, Ft.	Maximum Flow Rate* CFS	Maximum Flow Rate* MGD
22½°	0.2	.009	.006	2.0	2.81	1.82
30°	0.2	.012	.008	2.0	3.82	2.47
45°	0.2	.019	.012	2.0	5.85	3.78
60°	0.2	.026	.017	2.0	8.16	5.28
90°	0.2	.045	.029	2.0	14.14	9.14

*NOTE: CFS = Cubic Feet per Second
MGD = Million Gallons per Day

Source :ISCO Open Channel Flow Measurement Handbook Instrumentation Specialties Co.; Lincoln, Nebraska

TABLE 9-2

FLOW THROUGH 90° V-NOTCH WEIR

Flow (CFS) = $2.500 \left(\frac{H}{12}\right)^{2.5}$ Flow (MGD) = $1.616 \left(\frac{H}{12}\right)^{2.5}$

Head, H (Inches)	Flow CFS	Flow MGD	Head, H (Inches)	Flow CFS	Flow MGD	Head, H (Inches)	Flow CFS	Flow MGD
0	.0000	.0000	3¾	.1365	.0882	13	3.054	1.974
⅛	.0001	.0000	4	.1604	.1037	13½	3.356	2.169
¼	.0002	.0001	4¼	.1866	.1206	14	3.675	2.376
⅜	.0004	.0003	4½	.2153	.1392	14½	4.012	2.594
½	.0009	.0006	4¾	.2464	.1593	15	4.367	2.823
⅝	.0015	.0010	5	.2802	.1811	15½	4.740	3.064
¾	.0024	.0016	5¼	.3165	.2046	16	5.132	3.317
⅞	.0036	.0023	5½	.3555	.2298	16½	5.542	3.583
1	.0050	.0032	5½	.3973	.2568	17	5.972	3.860
1⅛	.0067	.0043	6	.4419	.2857	17½	6.421	4.150
1¼	.0088	.0057	6½	.5398	.3490	18	6.889	4.453
1⅜	.0111	.0072	7	.6497	.4200	18½	7.378	4.769
1½	.0138	.0089	7½	.7720	.4990	19	7.886	5.098
1⅝	.0169	.0109	8	.9072	.5864	19½	8.415	5.440
1¾	.0203	.0131	8½	1.056	.6824	20	8.965	5.795
1⅞	.0241	.0156	9	1.218	.7872	20½	9.536	6.164
2	.0284	.0183	9½	1.394	.9012	21	10.13	6.547
2¼	.0381	.0246	10	1.585	1.024	21½	10.74	6.944
2½	.0495	.0320	10½	1.790	1.157	22	11.38	7.354
2¾	.0629	.0406	11	2.011	1.300	22½	12.03	7.779
3	.0791	.0505	11½	2.248	1.453	23	12.71	8.219
3¼	.0954	.06177	12	2.500	1.616	23½	13.42	8.673
3½	.1149	.0742	12½	2.769	1.790	24	14.14	9.141

TABLE 9-3

FLOW THROUGH 60˚ V-NOTCH WEIR

Flow (CFS) = 1.443 $\left(\frac{H}{12}\right)^{2.5}$

Flow (MGD) = 0.933 $\left(\frac{H}{12}\right)^{2.5}$

Head, H (Inches)	Flow CFS	Flow MGD	Head, H (Inches)	Flow CFS	Flow MGD	Head, H (Inches)	Flow CFS	Flow MGD
0	.0000	.0000	3¾	.0788	.0509	13	1.763	1.140
⅛	.0000	.0000	4	.0926	.0599	13½	1.937	1.252
¼	.0001	.0001	4¼	.1077	.0696	14	2.121	1.372
⅜	.0002	.0002	4½	.1243	.0803	14½	2.316	1.497
½	.0005	.0003	4¾	.1422	.0920	15	2.521	1.630
⅝	.0009	.0006	5	.1617	.1046	15½	2.736	1.769
¾	.0014	.0009	5¼	.1827	.1181	16	2.962	1.915
⅞	.0021	.0013	5½	.2052	.1327	16½	3.199	2.068
1	.0029	.0019	5¾	.2293	.1483	17	3.447	2.229
1⅛	.0039	.0025	6	.2551	.1649	17½	3.706	2.396
1¼	.0051	.0033	6½	.3116	.2015	18	3.976	2.571
1⅜	.0064	.0041	7	.3750	.2425	18½	4.258	2.753
1½	.0080	.0052	7½	.4456	.2881	19	4.552	2.943
1⅝	.0097	.0063	8	.5236	.3386	19½	4.857	3.141
1¾	.0117	.0075	8½	.6093	.3940	20	5.175	3.346
1⅞	.0139	.0090	9	.7029	.4545	20½	5.504	3.559
2	.0164	.0106	9½	.8047	.5203	21	5.846	3.780
2¼	.0220	.0142	10	.9147	.5915	21½	6.200	4.009
2½	.0286	.0185	10½	1.033	.6682	22	6.567	4.246
2¾	.0363	.0235	11	1.161	.7506	22½	6.947	4.491
3	.0451	.0292	11½	1.297	.8388	23	7.339	4.745
3¼	.0551	.0356	12	1.443	.9330	23½	7.744	5.007
3½	.0663	.0429	12 ½	1.598	1.033	24	8.163	5.278

TABLE 9-4

RECOMMENDED FLOW RATES FOR RECTANGULAR WEIRS

Crest Length Ft.	Minimum Head Ft.	Minimum Flow Rate* CFS	Minimum Flow Rate* MGD	Maximum Head Ft.	Maximum Flow Rate* CFS	Maximum Flow Rate* MGD
WITH END CONTRACTIONS						
1	0.2	.286	.185	0.5	1.06	.685
1½	0.2	.435	.281	0.75	2.92	1.89
2	0.2	.584	.377	1.0	5.99	3.87
2½	0.2	.733	.474	1.25	10.5	6.77
3	0.2	.882	.570	1.5	16.5	10.7
4	0.2	1.18	.762	2.0	33.9	21.9
5	0.2	1.48	.955	2.5	59.2	38.3
6	0.2	1.77	1.15	3.0	93.4	60.4
8	0.2	2.37	1.53	4.0	192	124
10	0.2	2.97	1.92	5.0	335	217
WITHOUT END CONTRACTIONS						
1	0.2	.298	.192	0.5	1.18	.761
1½	0.2	.447	.289	0.75	3.24	2.10
2	0.2	.596	.385	1.0	6.66	4.30
2½	0.2	.745	.481	1.25	11.6	7.52
3	0.2	.894	.577	1.5	18.4	11.9
4	0.2	1.19	.770	2.0	37.7	24.3
5	0.2	1.49	.962	2.5	65.8	42.5
6	0.2	1.79	1.16	3.0	104	67.1
8	0.2	2.38	1.54	4.0	213	138
10	0.2	2.98	1.92	5.0	372	241

*NOTE: CFS = Cubic Feet per Second
MGD = Million Gallons per Day

Source: ISCO Open Channel Flow Measurement Handbook
Instrumentation Specialties Co., Lincoln, Nebraska

TABLE 9-5

FLOW THROUGH RECTANGULAR WEIRS WITH END CONTRACTIONS

Flow (CFS) = $3.33\,(L - \frac{H}{60})(\frac{H}{12})^{1.5}$

Flow (MGD) = $2.15\,(L - \frac{H}{60})(\frac{H}{12})^{1.5}$

	Flow									
Head, H	L = 1.0 Ft.		L = 1.5 Ft.		L = 2.0 Ft.		L = 2.5 Ft.		L = 3.0 Ft.	
(Inches)	CFS	MGD	CFS	MGD	CFS	MGD	CFS	MGD	CFS	MGD
0	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
⅛	.0035	.0023	.0053	.0034	.0071	.0046	.0088	.0057	.0106	.0070
¼	.0100	.0064	.0150	.0097	.0200	.0129	.0250	.0161	.0300	.0194
⅜	.0183	.0118	.0275	.0177	.0367	.0237	.0459	.0296	.0551	.0356
½	.0281	.0181	.0422	.0273	.0564	.0364	.0706	.0456	.0847	.0547
⅝	.0392	.0253	.0590	.0381	.0788	.0508	.0985	.0636	.1183	.0764
¾	.0514	.0332	.0774	.0500	.0134	.0668	.1294	.0836	.1554	.1004
⅞	.0646	.0417	.0974	.0629	.1302	.0840	.1630	.1052	.1957	.1264
1	.0788	.0509	.1188	.0767	.1589	.1026	.1989	.1284	.2390	.1543
1⅛	.0938	.0606	.1416	.0914	.1894	.1223	.2372	.1531	.2850	.1840
1¼	.1096	.0708	.1656	.1069	.2216	.1431	.2776	.1792	.3335	.2153
1⅜	.1262	.0815	.1908	.1232	.2554	.1649	.3199	.2066	.3845	.2483
1½	.1435	.0926	.2171	.1402	.2907	.1877	.3642	.2352	.4378	.2827
1⅝	.1614	.1042	.2444	.1578	.3274	.2114	.4104	.2649	.4933	.3185
1¾	.1800	.1162	.2728	.1761	.3655	.2360	.4582	.2958	.5509	.3557
1⅞	.1992	.1286	.3021	.1950	.4049	.2614	.5078	.3278	.6106	.3942
2	.2190	.1414	.3323	.2146	.4456	.2877	.5589	.3608	.6722	.4340
2¼	.2602	.1680	.3954	.2553	.5306	.3426	.6658	.4298	.8009	.5171
2½	.3035	.1959	.4618	.2981	.6201	.4004	.7784	.5026	.9368	.6048
2¾	.3486	.2251	.5312	.3430	.7139	.4609	.8966	.5789	1.079	.6968
3	.3954	.2553	.6036	.3897	.8117	.5241	1.020	.6584	1.228	.7928
3¼	.4439	.2866	.6786	.4381	.9133	.5897	1.148	.7412	1.383	.8927
3½	.4939	.3189	.7562	.4882	1.018	.6576	1.281	.8269	1.543	.9962
3¾	.5454	.3521	.8362	.5399	1.127	.7277	1.418	.9155	1.709	1.103
4	.5981	.3862	.9186	.5931	1.239	.8000	1.559	1.007	1.880	1.214
4¼	.6522	.4211	1.003	.6476	1.354	.8742	1.705	1.101	2.056	1.327
4½	.7073	.4567	1.090	.7036	1.472	.9504	1.854	1.197	2.237	1.444
4¾	.7636	.4930	1.178	.7608	1.593	1.028	2.008	1.296	2.422	1.564
5	.8210	.5301	1.269	.8192	1.717	1.108	2.164	1.397	2.612	1.687
5¼	.8793	.5677	1.361	.8788	1.843	1.190	2.325	1.501	2.807	1.812
5½	.9386	.6060	1.455	.9395	1.972	1.273	2.488	1.607	3.005	1.940
5¾	.9987	.6448	1.551	1.001	2.103	1.358	2.655	1.714	3.208	2.071
6	1.060	.6841	1.648	1.064	2.237	1.444	2.826	1.824	3.414	2.204
6½	-	-	1.847	1.193	2.511	1.621	3.175	2.050	3.839	2.478
7	-	-	2.052	1.325	2.794	1.804	3.536	2.283	4.278	2.762
7½	-	-	2.262	1.461	3.085	1.992	3.908	2.523	4.730	3.054
8	-	-	2.477	1.599	3.384	2.185	4.290	2.770	5.196	3.355
8½	-	-	2.697	1.741	3.689	2.382	4.682	3.023	5.674	3.664
9	-	-	2.920	1.885	4.001	2.583	5.083	3.282	6.164	3.980
9½	-	-	-	-	4.320	2.789	5.493	3.546	6.665	4.304
10	-	-	-	-	4.644	2.999	5.911	3.816	7.177	4.634
10½	-	-	-	-	4.974	3.212	6.337	4.091	7.700	4.971
11	-	-	-	-	5.309	3.428	6.771	4.371	8.232	5.315

Table 9-5 (continued)

Head, H (Inches)	L = 1.0 Ft. CFS	L = 1.0 Ft. MGD	L = 1.5 Ft. CFS	L = 1.5 Ft. MGD	L = 2.0 Ft. CFS	L = 2.0 Ft. MGD	L = 2.5 Ft. CFS	L = 2.5 Ft. MGD	L = 3.0 Ft. CFS	L = 3.0 Ft. MGD
11½	-	-	-	-	5.649	3.647	7.211	4.656	8.773	5.665
12	-	-	-	-	5.994	3.870	7.659	4.945	9.324	6.020
12½	-	-	-	-	-	-	8.113	5.238	9.883	6.381
13	-	-	-	-	-	-	8.573	5.535	10.45	6.748
13½	-	-	-	-	-	-	9.040	5.836	11.03	7.119
14	-	-	-	-	-	-	9.512	6.141	11.61	7.496
14½	-	-	-	-	-	-	9.989	6.449	12.20	7.877
15	-	-	-	-	-	-	10.47	6.761	12.80	8.263
15½	-	-	-	-	-	-	-	-	13.40	8.653
16	-	-	-	-	-	-	-	-	14.01	9.048
16½	-	-	-	-	-	-	-	-	14.63	9.446
17	-	-	-	-	-	-	-	-	15.25	9.849
17½	-	-	-	-	-	-	-	-	15.88	10.25
18	-	-	-	-	-	-	-	-	16.52	10.66

TABLE 9-6

FLOW THROUGH RECTANGULAR WEIRS WITHOUT END CONTRACTIONS

Flow (CFS) = $3.33L\left(\frac{H}{12}\right)^{1.5}$

Flow (MGD) = $2.15L\left(\frac{H}{12}\right)^{1.5}$

Head, H (Inches)	L = 1.0 Ft. CFS	L = 1.0 Ft. MGD	L = 1.5 Ft. CFS	L = 1.5 Ft. MGD	L = 2.0 Ft. CFS	L = 2.0 Ft. MGD	L = 2.5 Ft. CFS	L = 2.5 Ft. MGD	L = 3.0 Ft. CFS	L = 3.0 Ft. MGD
0	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
⅛	.0035	.0023	.0053	.0034	.0071	.0046	.0089	.0057	.0106	.0069
¼	.0100	.0065	.0150	.0097	.0200	.0129	.0250	.0162	.0300	.0194
⅜	.0184	.0119	.0276	.0178	.0368	.0238	.0460	.0297	.0552	.0357
½	.0283	.0183	.0425	.0274	.0566	.0366	.0708	.0458	.0850	.0549
⅝	.0396	.0256	.0594	.0383	.0792	.0511	.0990	.0640	.1187	.0767
¾	.0520	.0336	.0780	.0504	.1041	.0672	.1301	.0841	.1561	.1009
⅞	.0656	.0423	.0984	.0635	.1311	.0847	.1639	.1059	.1967	.1271
1	.0801	.0517	.1202	.0776	.1602	.1034	.2003	.1294	.2403	.1553
1⅛	.0956	.0617	.1434	.0926	.1912	.1234	.2390	.1544	.2886	.1853
1¼	.1120	.0723	.1679	.1084	.2239	.1446	.2799	.1809	.3359	.2171
1⅜	.1292	.0834	.1937	.1251	.2583	.1668	.3229	.2087	.3875	.2504
1½	.1472	.0950	.2207	.1425	.2943	.1900	.3679	.2378	.4415	.2853
1⅝	.1659	.1071	.2489	.1607	.3319	.2143	.4149	.2681	.4978	.3217
1¾	.1855	.1197	.2782	.1796	.3709	.2395	.4636	.2996	.5564	.3596
1⅞	.2057	.1328	.3085	.1992	.4113	.2656	.5142	.3323	.6170	.3988
2	.2266	.1463	.3399	.2194	.4532	.2926	.5664	.3661	.6797	.4393
2¼	.2704	.1746	.4055	.2618	.5407	.3491	.6759	.4368	.8111	.5242
2½	.3167	.2044	.4750	.3067	.6333	.4089	.7916	.5116	.9500	.6140
2¾	.3653	.2359	.5480	.3538	.7306	.4717	.9133	.5903	1.096	.7083

Table 9-6 (continued)

Head, H (Inches)	Flow L = 1.0 Ft. CFS	MGD	L = 1.5 Ft. CFS	MGD	L = 2.0 Ft. CFS	MGD	L = 2.5 Ft. CFS	MGD	L = 3.0 Ft. CFS	MGD
3	.4163	.2688	.6244	.4031	.8325	.5375	1.041	.6726	1.249	.8071
3¼	.4694	.3030	.7040	.4546	.9387	.6061	1.173	.7584	1.408	.9100
3½	.5245	.3387	.7868	.5080	1.049	.6773	1.311	.8475	1.574	1.017
3¾	.5817	.3756	.8726	.5634	1.164	.7512	1.454	.9399	1.745	1.128
4	.6409	.4138	.9613	.6207	1.282	.8275	1.602	1.036	1.923	1.243
4¼	.7019	.4532	1.053	.6797	1.404	.9063	1.755	1.134	2.206	1.361
4½	.7647	.4937	1.147	.7406	1.529	.9875	1.912	1.236	2.294	1.483
4¾	.8293	.5354	1.244	.8032	1.659	1.071	2.073	1.340	2.488	1.608
5	.8956	.5783	1.343	.8674	1.791	1.157	2.239	1.447	2.687	1.737
5¼	.9636	.6222	1.445	.9332	1.927	1.244	2.409	1.557	2.891	1.868
5½	1.033	.6671	1.550	1.001	2.067	1.334	2.583	1.670	3.100	2.003
5¾	1.105	.7131	1.657	1.070	2.209	1.426	2.761	1.785	3.314	2.142
6	1.177	.7601	1.766	1.140	2.355	1.520	2.943	1.902	3.532	2.283
6½	-	-	1.991	1.286	2.655	1.714	3.319	2.145	3.983	2.574
7	-	-	2.225	1.437	2.967	1.916	3.709	2.397	4.451	2.877
7½	-	-	2.468	1.594	3.291	2.125	4.113	2.659	4.936	3.190
8	-	-	2.719	1.756	3.625	2.341	4.532	2.929	5.438	3.515
8½	-	-	2.978	1.923	3.970	2.564	4.963	3.208	5.956	3.849
9	-	-	3.244	2.095	4.326	2.793	5.407	3.495	6.489	4.194
9½	-	-	-	-	4.691	3.029	5.864	3.790	7.037	4.548
10	-	-	-	-	5.066	3.271	6.333	4.093	7.600	4.912
10½	-	-	-	-	5.451	3.520	6.814	4.404	8.177	5.285
11	-	-	-	-	5.845	3.774	7.306	4.722	8.768	5.667
11½	-	-	-	-	6.248	4.034	7.810	5.048	9.372	6.057
12	-	-	-	-	6.660	4.300	8.325	5.380	9.990	6.457
12½	-	-	-	-	-	-	8.851	5.720	10.62	6.864
13	-	-	-	-	-	-	9.387	6.067	11.26	7.280
13½	-	-	-	-	-	-	9.934	6.420	11.92	7.704
14	-	-	-	-	-	-	10.49	6.780	12.59	8.136
14½	-	-	-	-	-	-	11.06	7.147	13.27	8.576
15	-	-	-	-	-	-	11.63	7.519	13.96	9.023
15½	-	-	-	-	-	-	-	-	14.67	9.478
16	-	-	-	-	-	-	-	-	15.38	9.941
16½	-	-	-	-	-	-	-	-	16.11	10.41
17	-	-	-	-	-	-	-	-	16.84	10.89
17½	-	-	-	-	-	-	-	-	17.59	11.37
18	-	-	-	-	-	-	-	-	18.35	11.86

d. Trapezoidal (Cipoletti) Weirs

A trapezoidal weir is similar to a rectangular weir with end contractions except that the sides incline outwardly to produce an opening in the shape of a trapezoid. The sides are usually inclined at a ratio of 4 vertical to 1 horizontal. Trapezoidal weirs constructed at this 4 to 1 ratio are usually referred to as “Cipoletti” weirs in honor of the Italian scientist Caesar Cipoletti who pioneered the use of the weir.

A trapezoidal weir can be used for a slightly greater range of flows than a rectangular weir. However, the accuracy of a trapezoidal weir is slightly less than that of rectangular or v-notch weirs. The minimum recommended head for a trapezoidal weir is 0.2 feet. The maximum head is recommended to be no more than one-half the length of the crest. Table 9-7 lists the minimum and maximum recommended flows for a trapezoidal (Cipoletti) weir. A discharge table for trapezoidal weirs with crest lengths up to three (3) feet is presented in Table 9-8.

TABLE 9-7

RECOMMENDED FLOW RATES FOR TRAPEZOIDAL (CIPOLETTI) WEIR

Crest Length, Ft.	Minimum Head Ft.	Minimum Flow Rate* CFS	Minimum Flow Rate* MGD	Maximum Head, Ft.	Maximum Flow Rate* CFS	Maximum Flow Rate* MGD
1	0.2	.301	.195	0.5	1.19	.769
1½	0.2	.452	.292	0.75	3.28	2.12
2	0.2	.602	.389	1.0	6.73	4.35
2½	0.2	.753	.487	1.25	11.8	7.60
3	0.2	.903	.584	1.5	18.6	12.0
4	0.2	1.20	.778	2.0	38.1	24.6
5	0.2	1.51	.973	2.5	66.5	43.0
6	0.2	1.81	1.17	3.0	105	67.8
8	0.2	2.41	1.56	4.0	214	139
10	0.2	3.01	1.95	5.0	375	243

*NOTE: CFS = Cubic Feet Per Second
MGD = Million Gallons Per Day

Source: ISCO Open Channel Flow Measurement Handbook Instrumentation Specialties Co., Lincoln, Nebraska

TABLE 9-8

FLOW THROUGH TRAPEZOIDAL WEIRS

Flow (CFS) = $3.367L\left(\frac{H}{12}\right)^{1.5}$

Flow (MGD) = $2.176L\left(\frac{H}{12}\right)^{1.5}$

Head, H	Flow									
	L = 1.0 Ft.		L = 1.5 Ft.		L = 2.0 Ft.		L = 2.5 Ft.		L = 3.0 Ft.	
(Inches)	CFS	MGD	CFS	MGD	CFS	MGD	CFS	MGD	CFS	MGD
0	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
1/8	.0036	.0023	.0054	.0035	.0072	.0046	.0089	.0058	.0107	.0069
1/4	.0101	.0065	.0152	.0098	.0202	.0131	.0253	.0164	.0304	.0196
3/8	.0186	.0120	.0279	.0180	.0372	.0240	.0465	.0301	.0558	.0361
1/2	.0286	.0185	.0430	.0278	.0573	.0370	.0716	.0463	.0859	.0555
5/8	.0400	.0259	.0600	.0388	.0800	.0517	.1001	.0647	.1201	.0776
3/4	.0526	.0340	.0789	.0510	.1052	.0680	.1315	.0850	.1578	.1020
7/8	.0663	.0428	.0994	.0643	.1326	.0857	.1657	.1071	.1989	.1285
1	.0810	.0523	.1215	.0785	.1620	.1047	.2025	.1309	.2430	.1570
1 1/8	.0966	.0625	.1450	.0937	.1933	.1249	.2416	.1562	.2899	.1874
1 1/4	.1132	.0732	.1698	.1097	.2264	.1463	.2830	.1829	.3396	.2195
1 3/8	.1306	.0844	.1959	.1266	.2612	.1688	.3265	.2110	.3918	.2532
1 1/2	.1488	.0962	.2232	.1443	.2976	.1923	.3720	.2404	.4464	.2885
1 5/8	.1678	.1084	.2517	.1627	.3356	.2169	.4195	.2711	.5034	.3253
1 3/4	.1875	.1212	.2813	.1818	.3750	.2424	.4688	.3030	.5625	.3636
1 7/8	.2080	.1344	.3199	.2016	.4159	.2688	.5199	.3360	.6239	.4032
2	.2291	.1481	.3436	.2221	.4582	.2961	.5727	.3702	.6873	.4442
2 1/4	.2734	.1767	.4100	.2650	.5467	.3534	.6834	.4417	.8201	.5300
2 1/2	.3202	.2069	.4803	.3104	.6403	.4139	.8004	.5173	.9605	.6208
2 3/4	.3694	.2387	.5541	.3581	.7388	.4775	.9234	.5968	1.108	.7162
3	.4209	.2720	.6313	.4080	.8418	.5440	1.052	.6800	1.263	.8160
3 1/4	.4746	.3067	.7118	.4601	.9491	.6134	1.186	.7668	1.424	.9201
3 1/2	.5304	.3428	.7955	.5142	1.061	.6855	1.326	.8569	1.591	1.028
3 3/4	.5882	.3801	.8823	.5702	1.176	.7603	1.471	.9504	1.765	1.140
4	.6480	.4188	.9720	.6282	1.296	.8376	1.620	1.047	1.944	1.256
4 1/4	.7097	.4587	1.065	.6880	1.419	.9173	1.774	1.147	2.129	1.376
4 1/2	.7732	.4997	1.160	.7496	1.546	.9994	1.933	1.249	2.320	1.499
4 3/4	.8385	.5419	1.258	.8129	1.677	1.084	2.096	1.355	2.516	1.626
5	.9056	.5853	1.358	.8779	1.811	1.171	2.264	1.463	2.717	1.756
5 1/4	.9743	.6297	1.462	.9446	1.949	1.259	2.436	1.574	2.923	1.889
5 1/2	1.045	.6752	1.567	1.013	2.090	1.351	2.612	1.688	3.134	2.026
5 3/4	1.117	.7218	1.675	1.083	2.234	1.444	2.792	1.805	3.350	2.165
6	1.190	.7694	1.786	1.154	2.381	1.539	2.976	1.923	3.571	2.308
6 1/2	-	-	2.013	1.301	2.685	1.735	3.356	2.169	4.027	2.603
7	-	-	2.250	1.454	3.000	1.939	3.750	2.424	4.500	2.909
7 1/2	-	-	2.496	1.613	3.327	2.150	4.159	2.688	4.991	3.226
8	-	-	2.749	1.777	3.666	2.369	4.582	2.961	5.498	3.554
8 1/2	-	-	3.011	1.946	4.015	2.595	5.018	3.243	6.022	3.892
9	-	-	3.280	2.120	4.374	2.827	5.467	3.534	6.561	4.240
9 1/2	-	-	-	-	4.743	3.066	5.929	3.832	7.115	4.599
10	-	-	-	-	5.123	3.311	6.403	4.139	7.684	4.966
10 1/2	-	-	-	-	5.512	3.562	6.890	4.453	8.268	5.343

Table 9-8 (Continued)

Head, H	Flow									
	L = 1.0 Ft.		L = 1.5 Ft.		L = 2.0 Ft.		L = 2.5 Ft.		L = 3.0 Ft.	
(Inches)	CFS	MGD	CFS	MGD	CFS	MGD	CFS	MGD	CFS	MGD
11	-	-	-	-	5.910	3.820	7.388	4.775	8.865	5.730
11½	-	-	-	-	6.318	4.083	7.897	5.104	9.476	6.125
12	-	-	-	-	6.734	4.352	8.418	5.440	10.10	6.528
12½	-	-	-	-	-	-	8.949	5.784	10.74	6.941
13	-	-	-	-	-	-	9.491	6.134	11.39	7.361
13½	-	-	-	-	-	-	10.04	6.492	12.05	7.790
14	-	-	-	-	-	-	10.61	6.856	12.73	8.227
14½	-	-	-	-	-	-	11.18	7.226	13.42	8.671
15	-	-	-	-	-	-	11.76	7.603	14.12	9.124
15½	-	-	-	-	-	-	-	-	14.83	9.584
16	-	-	-	-	-	-	-	-	15.55	10.05
16½	-	-	-	-	-	-	-	-	16.29	10.53
17	-	-	-	-	-	-	-	-	17.03	11.01
17½	-	-	-	-	-	-	-	-	17.79	11.50
18	-	-	-	-	-	-	-	-	18.56	11.99

9-4 FLUMES

a. General Information

Flumes are specially shaped sections of open channels which are used to measure flows. A flume is constructed so that it provides a restriction in channel area and/or a change in channel slope which results in an increased velocity and change in the depth of the water flowing through the flume. Generally, flumes can measure a higher flow rate than a comparably sized weir. Also, flumes are self cleaning due to the high velocity they create and are consequently more suited to measuring flows which might contain sediment or solids. The major disadvantage of a flume is that it is typically more expensive to install than a weir.

There are several different types of flumes. However, only two are commonly used in the measurement of wastewater flows - Parshall flumes and Palmer-Bowlus flumes. Both of these flumes are used extensively in measuring flows in sewer systems and wastewater treatment plants. Each will be discussed in detail later in this chapter. Under normal conditions, both types of flumes are designed for measuring flows under “free flow” conditions in which there are no restrictions downstream of the flume that would create a backwater effect.

Just as it is with weirs, there are certain requirements that flumes should meet if they are to provide an accurate means of measuring flows. These requirements are as follows:

1. A flume should be located in a straight section of an open channel.
2. The flow which approaches a flume should be evenly distributed across the channel and reasonably free of turbulence and waves.
3. A flume should be located so that the velocity of the approaching flow is not excessively high.
4. The depth and upstream banks of the channel must be sufficient to handle the increased depth of flow produced by a flume.

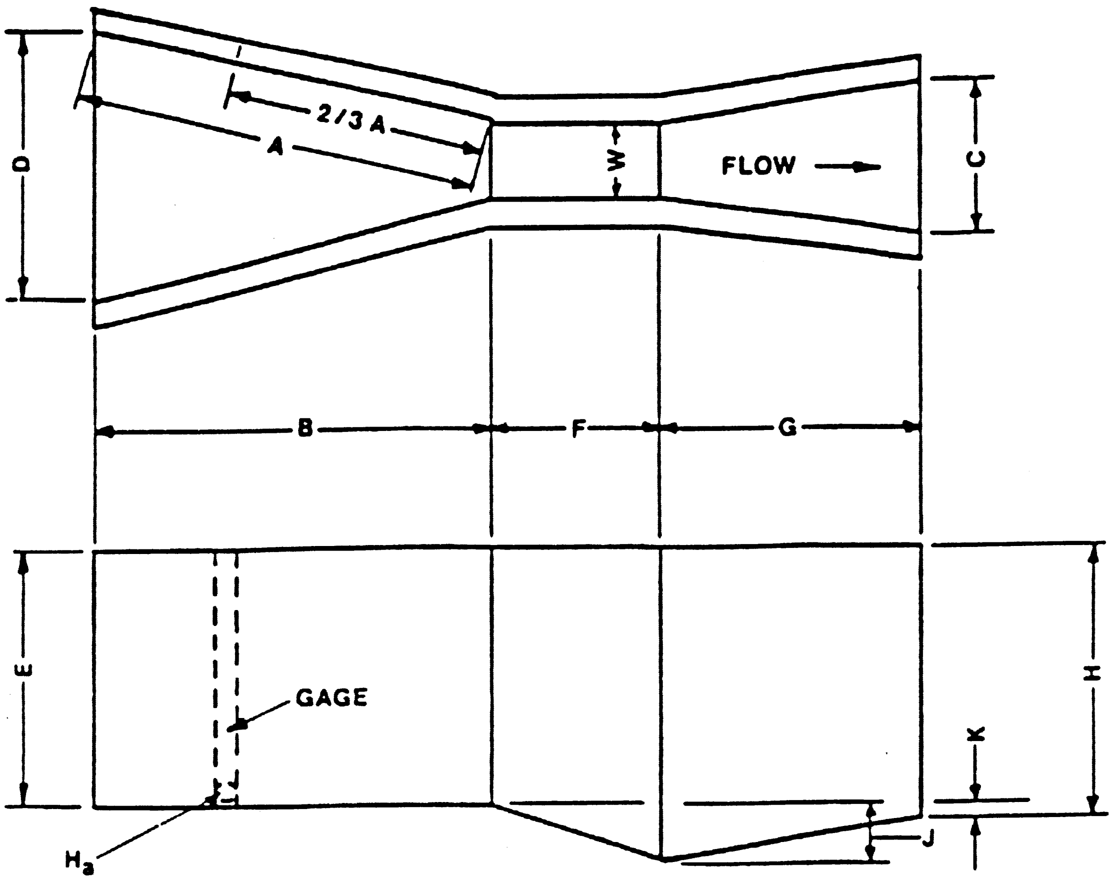
5. A flume should be located so that the possibility of backwater effects from downstream restrictions is eliminated or at least minimized.

b. Parshall Flumes

The most common flume in measuring wastewater flows is the Parshall flume which was developed in 1922 by Dr. Ralph L. Parshall of the U.S. Soil Conservation Service for measuring irrigation water. Exhibit 9-2 illustrates the details and dimensions of Parshall flumes and Exhibit 9-3 shows an actual flume in operation at a Mississippi wastewater treatment facility.

The flume features a constricted throat that produces a head that can be related to flow rate. Flow rate can be computed by measuring the depth of flow or head (H) at a specified point upstream of the throat (See Exhibit 9-2). It has a level converging section upstream of the throat which accelerates the entering flow and helps to eliminate solids and sediment from settling. The size of a Parshall flume is designated by the width (W) of its throat as shown in Exhibit 9-2. For a particular throat width, the other dimensions of the flume must strictly conform to specific requirements. Flumes are constructed of wood, concrete, galvanized sheet metal, and fiber glass.

Parshall flumes have the capability to function over a wide range of flow rates and head conditions. Table 9-9 shows the recommended flow rates and head conditions for various size Parshall flumes up to twelve (12) feet. Discharge tables for 3-inch, 6-inch, 9-inch, and 1-foot Parshall flumes are presented in Tables 9-10 thru 9-13 respectively.



Throat Width W (IN)	A	2/3 A	B	C	D	E	F	G	H	J	K
	DIMENSIONS										
1"	1'-2-9/32"	0'-9-17/32"	1'-2"	0'-3-21/32"	0'-6-19/32"	0'-9"	0'-3"	0'-8"	0'-9-3/4"	1-1/8"	3/4"
2"	1'-4-5/16"	0'-10-7/8"	1'-4"	0'-5-5/16"	0'-8-13/32"	0'-9"	0'-4-1/2"	0'-10"	0'-9-7/8"	1-11/16"	7/8"
3"	1'-6-3/8"	1'-0-1/4"	1'-6"	0'-7"	0'-10-3/16"	2'-0"	0'-6"	1'-0"	2'-1"	2-1/4"	1"
6"	2'-0-7/16"	1'-4-5/16"	2'-0"	1'-3-1/2"	1'-3-5/8"	2'-0"	1'-0"	2'-0"	2'-3"	4-1/2"	3"
9"	2'-10-5/8"	1'-11-1/8"	2'-10"	1'-3"	1'-10-5/8"	2'-6"	1'-0"	1'-6"	2'-9"	4-1/2"	3"
12"	4'-6"	3'-0"	4'-4-7/8"	2'-0"	2'-9-1/4"	3'-0"	2'-0"	3'-0"	3'-3"	9"	3"
18"	4'-9"	3'-2"	4'-7-7/8"	2'-6"	3'-4-3/8"	3'-0"	2'-0"	3'-0"	3'-3"	9"	3"
24"	5'-0"	3'-4"	4'-10-7/8"	3'-0"	3'-11-1/2"	3'-0"	2'-0"	3'-0"	3'-3"	9"	3"
30"	5'-4-1/4"	3'-6-3/4"	5'-3"	3'-6"	4'-6-3/4"	3'-0"	2'-0"	3'-0"	3'-3"	9"	3"
36"	5'-6"	3'-8"	5'-4-3/4"	4'-0"	5'-1-7/8"	3'-0"	2'-0"	3'-0"	3'-3"	9"	3"
48"	6'-0"	4'-0"	5'-10-5/8"	5'-0"	6'-4-1/4"	3'-0"	2'-0"	3'-0"	3'-3"	9"	3"
60"	6'-6"	4'-4"	6'-4-1/2"	6'-0"	7'-6-5/8"	3'-0"	2'-0"	3'-0"	3'-3"	9"	3"
72"	7'-0"	4'-8"	6'-10-3/8"	7'-0"	8'-9"	3'-0"	2'-0"	3'-0"	3'-3"	9"	3"
84"	7'-6"	5'-0"	7'-4-1/4"	8'-0"	9'-11-3/8"	3'-0"	2'-0"	3'-0"	3'-3"	9"	3"
96"	8'-0"	5'-4"	7'-10-1/8"	9'-0"	11'-1-3/4"	3'-0"	2'-0"	3'-0"	3'-3"	9"	3"

EXHIBIT 9-2

DETAILS & DIMENSIONS OF PARSHALL FLUMES

Source: Manning Environmental Corporation Santa Cruz, California

EXHIBIT 9-3

PARSHALL FLUME

TABLE 9-9

RECOMMENDED FLOW RATES FOR PARSHALL FLUMES

Throat Width, W	Minimum Head, Ha Ft.	Minimum Flow Rate*		Maximum Head, Ha Ft.	Maximum Flow Rate*	
		CFS	MGD		CFS	MGD
1 In.	0.07	.005	.003	0.6	.153	.099
2 In.	0.07	.011	.007	0.6	.306	.198
3 In.	0.10	.028	.018	1.5	1.86	1.20
6 In.	0.10	.054	.035	1.5	3.91	2.53
9 In.	0.10	.091	.059	2.0	8.87	5.73
1 Ft.	0.10	.120	.078	2.5	16.1	10.4
1½ Ft.	0.10	.174	.112	2.5	24.6	15.9
2 Ft.	0.15	.423	.273	2.5	33.1	21.4
3 Ft.	0.15	.615	.397	2.5	50.4	32.6
4 Ft.	0.20	1.26	.816	2.5	67.9	43.9
5 Ft.	0.20	1.55	1.00	2.5	85.6	55.3
6 Ft.	0.25	2.63	1.70	2.5	103	66.9
8 Ft.	0.25	3.45	2.23	2.5	139	90.1
10 Ft.	0.30	5.74	3.71	3.5	292	189
12 Ft.	0.33	7.93	5.13	4.5	519	335

*NOTE: CFS = Cubic Feet Per Second
MGD = Million Gallons Per Day

Source: ISCO Open Channel Flow Measurement Handbook Instrumentation Specialties Co., Lincoln, Nebraska

TABLE 9-10

FLOW THROUGH A 3-INCH PARSHALL FLUME

$\text{Flow (CFS)} = 0.992\left(\frac{Ha}{12}\right)^{1.547}$

$\text{Flow (MGD)} = 0.641\left(\frac{Ha}{12}\right)^{1.547}$

Head, H	Flow		Head, H	Flow		Head, H	Flow	
(Inches)	CFS	MGD	(Inches)	CFS	MGD	(Inches)	CFS	MGD
0	.0000	.0000	2¾	.1015	.0656	9	.6357	.4108
1/8	.0009	.0006	3	.1162	.0751	9½	.6911	.4467
¼	.0025	.0016	3¼	.1315	.0850	10	.7482	.4836
⅜	.0047	.0030	3½	.1475	.0953	10½	.8069	.5215
½	.0073	.0047	3¾	.1641	.1060	11	.8671	.5604
⅝	.0103	.0066	4	.1813	.1172	11½	.9288	.6003
¾	.0136	.0088	4¼	.1991	.1287	12	.9920	.6411
⅞	.0173	.0112	4½	.2175	.1406	12½	1.057	.6829
1	.0212	.0137	4¾	.2365	.1529	13	1.123	.7256
1⅛	.0255	.0165	5	.2561	.1655	13½	1.190	.7693
1¼	.0300	.0194	5¼	.2761	.1785	14	1.259	.8138
1⅜	.0348	.0225	5½	.2967	.1918	14½	1.329	.8592
1½	.0398	.0257	5¾	.3179	.2054	15	1.401	.9055
1	.0450	.0291	6	.3395	.2194	15½	1.474	.9526
1¾	.0505	.0326	6½	.3842	.2483	16	1.548	1.001
1⅞	.0562	.0363	7	.4309	.2785	16½	1.624	1.049
2	.0620	.0401	7½	.4794	.3099	17	1.700	1.099
2¼	.0744	.0481	8	.5298	.3424	17½	1.778	1.149
2½	.0876	.0566	8½	.5819	.3761	18	1.858	1.201

TABLE 9-11

FLOW THROUGH A 6-INCH PARSHALL FLUME

$$\text{Flow (CFS)} = 2.06 \left(\frac{Ha}{12} \right)^{1.58} \qquad \text{Flow (MGD)} = 1.33 \left(\frac{Ha}{12} \right)^{1.58}$$

Head, H (Inches)	Flow CFS	Flow MGD	Head, H (Inches)	Flow CFS	Flow MGD	Head, H (Inches)	Flow CFS	Flow MGD
0	.0000	.0000	2¾	.2009	.1298	9	1.308	.8451
⅛	.0015	.0010	3	.2305	.1490	9½	1.424	.9204
¼	.0045	.0029	3¼	.2615	.1690	10	1.544	.9981
⅜	.0086	.0056	3½	.2940	.1900	10½	1.668	1.078
½	.0136	.0088	3¾	.3279	.2119	11	1.795	1.160
⅝	.0193	.0125	4	.3631	.2347	11½	1.926	1.245
¾	.0258	.0167	4¼	.3996	.2583	12	2.060	1.331
⅞	.0329	.0213	4½	.4374	.2827	12½	2.197	1.420
1	.0406	.0263	4¾	.4764	.3079	13	2.338	1.511
1⅛	.0489	.0316	5	.5166	.3339	13½	2.481	1.604
1¼	.0578	.0374	5¼	.5580	.3606	14	2.628	1.699
1⅜	.0672	.0434	5½	.6005	.3881	14½	2.778	1.795
1½	.0771	.0498	5¾	.6442	.4164	15	2.931	1.894
1⅝	.0875	.0565	6	.6890	.4453	15½	3.087	1.995
1¾	.0983	.0636	6½	.7819	.5054	16	3.245	2.098
1⅞	.1097	.0709	7	.8791	.5681	16½	3.407	2.202
2	.1214	.0785	7½	.9803	.6336	17	3.572	2.308
2¼	.1463	.0945	8	1.086	.7016	17½	3.739	2.417
2½	.1728	.1117	8½	1.195	.7721	18	3.909	2.527

TABLE 9-12

FLOW THROUGH A 9-INCH PARSHALL FLUME

Flow (CFS) = $3.07 \left(\frac{Ha}{12} \right)^{1.53}$ Flow (MGD) = $1.98 \left(\frac{Ha}{12} \right)^{1.53}$

Head, H (Inches)	Flow CFS	Flow MGD	Head, H (Inches)	Flow CFS	Flow MGD	Head, H (Inches)	Flow CFS	Flow MGD
0	.0000	.0000	3¾	.5179	.3347	13	3.470	2.243
⅛	.0028	.0018	4	.5717	.3695	13½	3.676	2.376
¼	.0082	.0053	4¼	.6272	.4054	14	3.887	2.512
⅜	.0153	.0099	4½	.6846	.4424	14½	4.101	2.650
½	.0237	.0153	4¾	.7436	.4806	15	4.319	2.792
⅝	.0334	.0216	5	.8043	.5198	15½	4.542	2.935
¾	.0441	.0285	5¼	.8666	.5601	16	4.768	3.081
⅞	.0559	.0361	5½	.9306	.6014	16½	4.997	3.230
1	.0685	.0443	5¾	.9961	.6437	17	5.231	3.381
1⅛	.0821	.0531	6	1.063	.6871	17½	5.468	3.534
1¼	.0964	.0623	6½	1.202	.7766	18	5.709	3.690
1⅜	.1116	.0721	7	1.346	.8698	18½	5.953	3.848
1½	.1275	.0824	7½	1.496	.9666	19	6.201	4.008
1⅝	.1441	.0931	8	1.651	1.067	19½	6.453	4.170
1¾	.1614	.1043	8½	1.811	1.171	20	6.708	4.335
1⅞	.1793	.1159	9	1.977	1.278	20½	6.966	4.502
2	.1980	.1279	9½	2.147	1.388	21	7.228	4.671
2¼	.2370	.1532	10	2.323	1.501	21½	7.492	4.842
2½	.2785	.1800	10½	2.503	1.618	22	7.761	5.016
2¾	.3222	.2083	11	2.687	1.737	22½	8.032	5.191
3	.3681	.2379	11½	2.877	1.859	23	8.307	5.369
3¼	.4161	.2689	12	3.070	1.984	23½	8.585	5.548
3½	.4660	.3012	12½	3.268	2.112	24	8.866	5.730

TABLE 9-13

FLOW THROUGH A 12-INCH PARSHALL FLUME

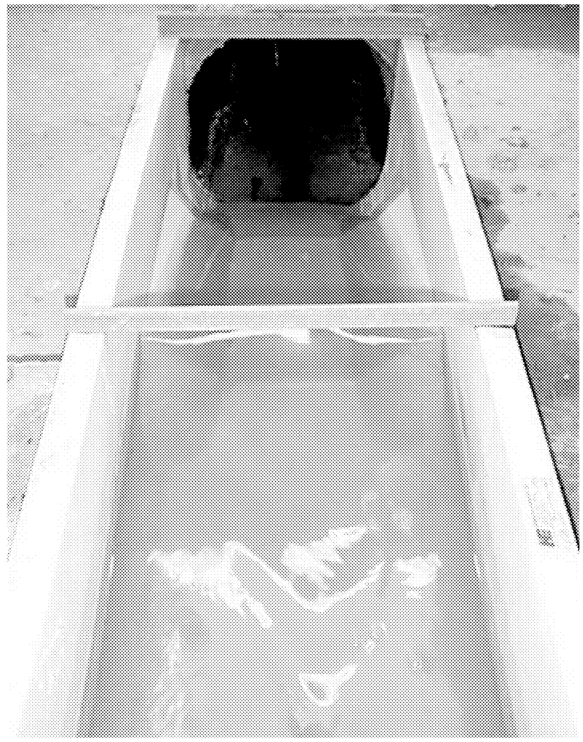
Flow (CFS) = $4.00 \left(\frac{Ha}{12}\right)^{1.522}$ Flow (MGD) = $2.59 \left(\frac{Ha}{12}\right)^{1.522}$

Head, H (Inches)	Flow CFS	Flow MGD	Head, H (Inches)	Flow CFS	Flow MGD	Head, H (Inches)	Flow CFS	Flow MGD
0	.0000	.0000	4¾	.9761	.6308	17	6.797	4.393
⅛	.0038	.0025	5	1.055	.6820	17½	7.103	4.591
¼	.0110	.0071	5¼	1.137	.7346	18	7.414	4.792
⅜	.0205	.0132	5½	1.220	.7885	18½	7.730	4.996
½	.0317	.0205	5¾	1.306	.8437	19	8.050	5.203
⅝	.0446	.0228	6	1.393	.9002	19½	8.375	5.413
¾	.0588	.0380	6½	1.573	1.017	20	8.704	5.625
⅞	.0744	.0481	7	1.761	1.138	20½	9.037	5.841
1	.0911	.0589	7½	1.956	1.264	21	9.375	6.059
1⅛	.1090	.0704	8	2.158	1.395	21½	9.717	6.280
1¼	.1280	.0827	8½	2.367	1.530	22	10.06	6.504
1⅜	.1479	.0956	9	2.582	1.669	22½	10.41	6.730
1½	.1689	.1091	9½	2.803	1.812	23	10.77	6.959
1⅝	.1908	.1233	10	3.031	1.959	23½	11.13	7.190
1¾	.2135	.1380	10½	3.264	2.110	24	11.49	7.424
1⅞	.2372	.1533	11	3.504	2.265	24½	11.85	7.661
2	.2616	.1691	11½	3.749	2.423	25	12.22	7.900
2¼	.3130	.2023	12	4.000	2.585	25½	12.60	8.142
2½	.3675	.2375	12½	4.256	2.751	26	12.98	8.386
2¾	.4248	.2746	13	4.518	2.920	26½	13.36	8.633
3	.4850	.3134	13½	4.785	3.093	27	13.74	8.882
3¼	.5478	.3541	14	5.058	3.269	27½	14.13	9.134
3½	.6132	.3963	14½	5.335	3.448	28	14.53	9.388
3¾	.6811	.4402	15	5.618	3.631	28½	14.92	9.644
4	.7514	.4856	15½	5.905	3.817	29	15.32	9.903
4¼	.8241	.5326	16	6.198	4.005	29½	15.73	10.16
4½	.8990	.5810	16½	6.495	4.198	30	16.13	10.43

c. Palmer-Bowlus Flumes

The Palmer-Bowlus flume was developed in the 1930's by Harold V. Palmer and Fred D. Bowlus of the Los Angeles County (California)Sanitation District. It is used most often in manholes or open round or rectangular conduits. The accuracy of a Palmer-Bowlus flume is comparable to that of a Parshall flume, but its useful range of flow rates is smaller than a Parshall flume.

The most unusual characteristic of a Palmer-Bowlus flume is that there is no specific cross-sectional shape as there is with a Parshall flume. The only requirement is that it be of uniform cross-section with a throat length approximately equal to the diameter of the pipe or channel in which it is to be installed. A commonly used Palmer-Bowlus flume is one with a trapezoidal cross-section as shown in Exhibit 9-4.



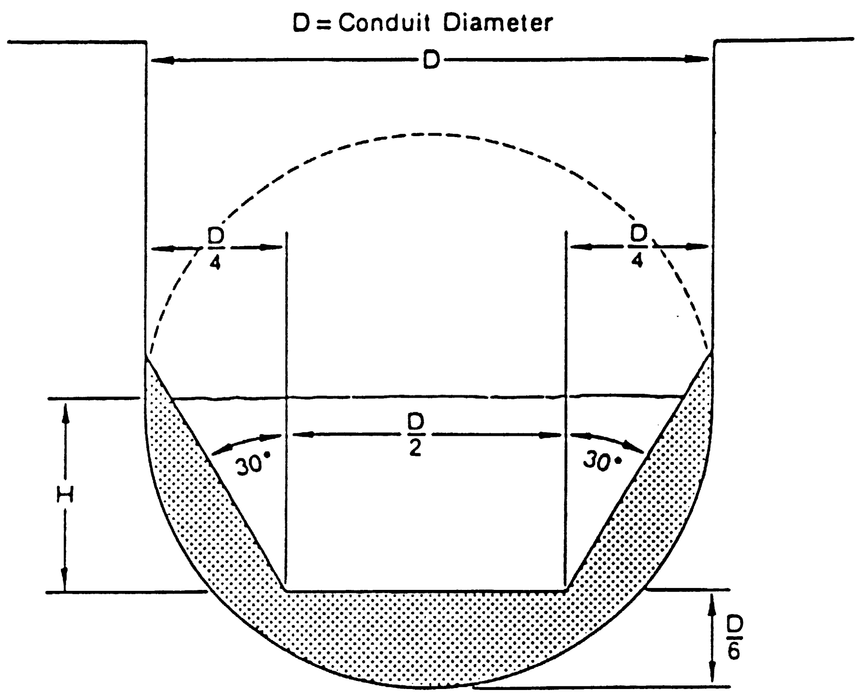


EXHIBIT 9-4

COMMON TRAPEZOIDAL CROSS SECTION FOR PALMER-BOWLUS FLUME

Source: ISCO Open Channel Flow Measurement Handbook Instrumentation Specialties Co.; Lincoln, Nebraska

Palmer-Bowlus flumes are designated by the size of the pipe or conduit into which they are placed. Standard sizes are usually available in sizes ranging from four (4) to forty-two (42) inches. The point at which head is measured in a Palmer-Bowlus flume is at a distance one-half of the diameter of the pipe or conduit upstream from the end of the throat. The pipe or conduit upstream of the flume should be sloped sufficiently to produce smooth hydraulic conditions through the throat. However, the upstream slope should not be too steep or else turbulence will be created by excessive velocities. As a general rule, the upstream slope should not exceed about 2 feet vertical drop per 100 feet of pipe (2% slope).

Because the cross-sectional shapes of Palmer-Bowlus flumes vary, it is difficult to establish firm recommendation for heads and flow rates. However, for flumes with trapezoidal cross-sections, the heads and flows shown in Table 9-14 are recommended. Discharge equations for Palmer-Bowlus flumes vary with the particular shape and dimension of a particular flume. Manufacturers of Palmer-Bowlus flumes usually provide “rating curves” with their flumes which establish flow rates for measured heads.

9-5 FLOW METERS & RECORDERS

There are numerous devices available which are used to measure flow rates directly or to measure “head” on a weir or flume. Direct measuring flow meters include such devices as magnetic flow meters, propeller meters, and Venturi tubes. These devices are not used in conjunction with weirs or flumes. Instead they can measure flow rates directly, usually through closed pipes.

Other devices are used to automatically measure “head” on a weir or flume then through electronically calibrated mechanisms to compute the flow rate. Such measuring devices include float gages, ultrasonic sensors, and capacitance probes. They are usually connected to a recording device which continuously records the computed flow rate on charts. Most activated sludge and trickling filter treatment plants are equipped with automatic flow measuring and recording equipment installed on a weir or flume. Exhibits 9-5 and 9-6 show examples of a float gage and automatic flow recorders in use at Mississippi wastewater treatment facilities.

Head on weirs and flumes can also be measured manually and flows computed from the measurements. Manual measurements are normally made by using a yardstick, ruler, tape, or similar graduated device or by reading directly from a staff gage which is often built into a flume or weir.

All automatic flow measuring and recording devices must be calibrated periodically to assure accuracy. As a general rule, calibration at least once a year is suggested. Virtually every automatic measuring and recording device is a highly sophisticated piece of equipment which should be calibrated and repaired only by properly trained and qualified technicians.

TABLE 9-14

RECOMMENDED FLOW RATES FOR TRAPEZOIDAL PALMER-BOWLUS FLUMES

Flume Size, Inches	Maximum Slope for Upstream (%)	Minimum Head, Ft.	Minimum Flow Rate*		Maximum Head, Ft.	Maximum Flow Rate*	
			CFS	MGD		CFS	MGD
6	2.2	0.11	0.035	0.023	0.36	0.315	0.203
8	2.0	0.15	0.074	0.048	0.49	0.670	0.433
10	1.8	0.18	0.122	0.079	0.61	1.16	0.752
12	1.6	0.22	0.198	0.128	0.73	1.83	1.18
15	1.5	0.27	0.334	0.216	0.91	3.18	2.06
18	1.4	0.33	0.549	0.355	1.09	5.01	3.24
21	1.4	0.38	0.780	0.504	1.28	7.44	4.81
24	1.3	0.44	1.12	0.721	1.46	10.4	6.70
27	1.3	0.49	1.46	0.945	1.64	13.8	8.95
30	1.3	0.55	1.95	1.26	1.82	18.0	11.6

*NOTE: CFS = Cubic Feet Per Second
MGD = Million Gallons Per Day

Source: ISCO Open Channel Flow Measurement Handbook Instrumentation Specialties Co., Lincoln, Nebraska

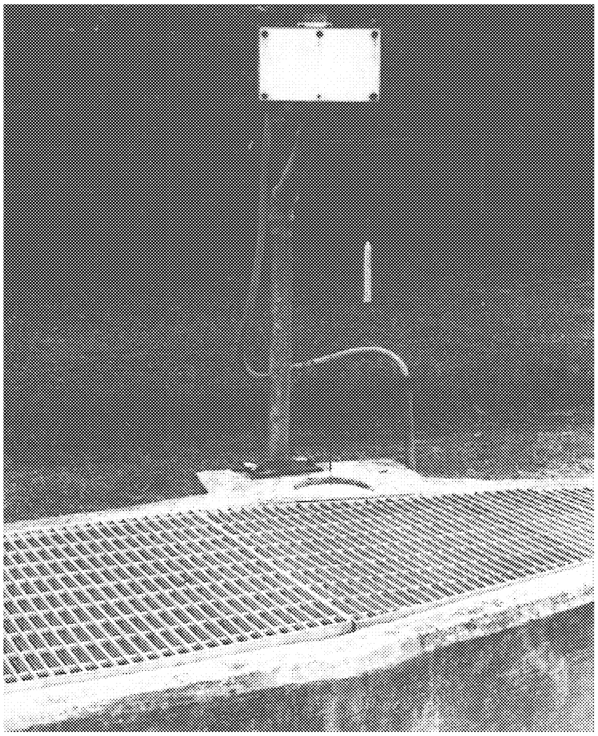


EXHIBIT 9-5

FLOAT GAUGE FOR MEASURING HEAD ON FLUME

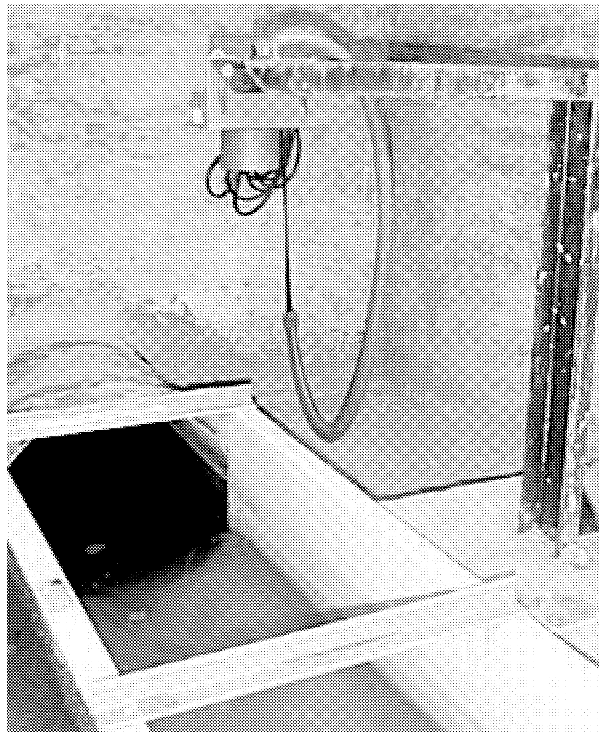
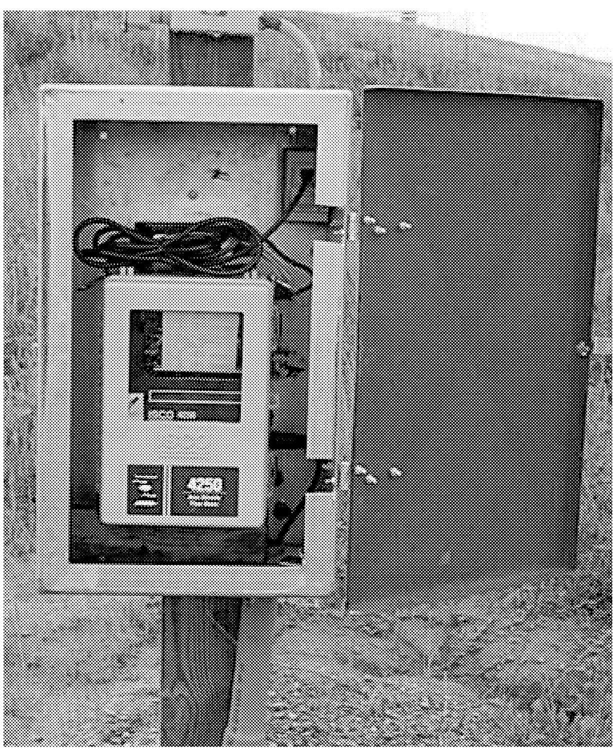


EXHIBIT 9-5A

ULTRASONIC TRANSDUCER FOR MEASURING HEAD ON FLUME



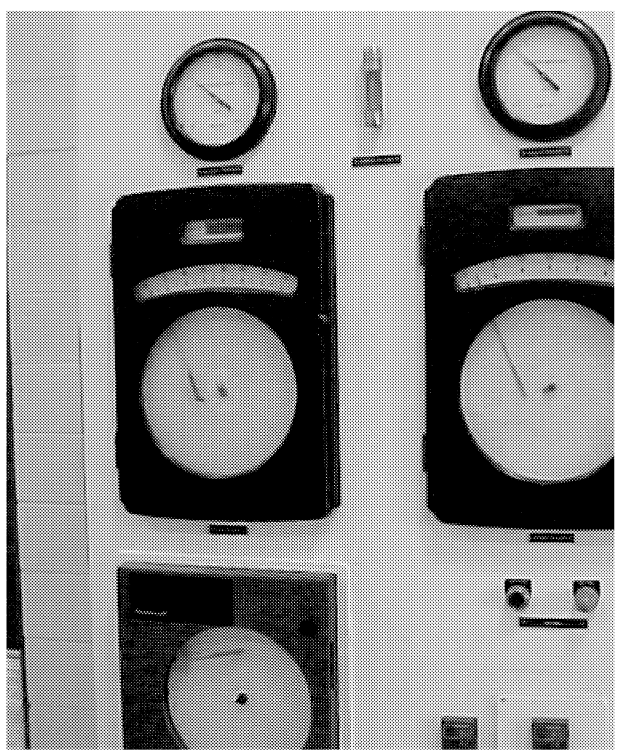


EXHIBIT 9-6

AUTOMATIC FLOW RECORDERS

CHAPTER 10

COLLECTION SYSTEMS

* * * * *

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CHAPTER 10

COLLECTION SYSTEMS

10-1 HISTORICAL BACKGROUND

Credit is generally given to the ancient Romans for first using sewers. Early sewers in this country were originally constructed only to collect storm water. Much of the basic principles dealing with hydraulic capacities, wastewater flow rates, and similar factors which affect sewer design were first applied in the mid 1800's. Since that time, these principles have been researched and developed into the practical applications which are used today. Little is known about specific sewer systems in the United States prior to 1900 except that channels or troughs were utilized instead of circular pipe as is used today. However, it is known that one of the earliest sewer systems was constructed in Brooklyn, New York. Most of the early sewers were excessively over-sized; a situation that has been corrected in this century due to an ever-increasing knowledge of wastewater flow rates and pipe hydraulics. In the early 1900's the use of electricity became a more common occurrence in communities which opened the door for the use of pumping stations. With pumping stations available to help overcome problems with sewer depths and slopes, the construction of community sewers began to emerge. In 1972, it was estimated that there were over 430,000 miles of sewer and almost 37,000 wastewater pumping stations serving approximately 153,000,000 persons in the United States. Since then, many more systems have been added to communities through numerous publicly- and privately-funded construction projects.

10-2 DEFINITIONS

In discussing wastewater collection systems, there are certain basic terms which are widely used. It is important that the definitions and usage of these terms be understood by anyone whose occupation deals with wastewater collection. Some of the basic terms and their definitions are as follows:

1. Sewer - A pipe or conduit designed to transport wastewater and/or stormwater.
2. Sewage - Domestic wastewater; the contents in a sewer.
3. Sewerage - A system of sewers, pumping stations, and related appurtenances serving a community.
4. Wastewater - A community's water supply after it has been used for selected purposes such as residential, commercial, industrial, and institutional uses.
5. Infiltration - Groundwater which enters a sewer system from such sources as defective pipe, pipe joints, connections, manhole walls, etc. Infiltration does not include, and is distinguished from, inflow.
6. Inflow - Surface water, primarily stormwater, which enters a sewer system from such sources as roof drains, yard drains, drains from springs and swampy areas, cross connections from storm sewers, surface run-off, street drainage, etc. Inflow does not include, and is distinguished from, infiltration.
7. Infiltration/Inflow - The total quantity of water entering a sewer system from <u>both</u> infiltration and inflow sources.
8. Sanitary Sewer System - A sewer system that is designed to transport only <u>wastewater</u> from residential, commercial, institutional, and industrial sources. A sanitary sewer system normally will also carry flow from uncorrected or undetected infiltration and inflow sources.

9. Storm Sewer System - A sewer system that is designed to transport only stormwater, surface run-off, and other approved drainage. A storm sewer system is not intended to transport wastewaters.
10. Combined Sewer System - A sewer system designed to transport both wastewater and storm or surface water.
11. Building Sewer - The pipe or sewer which extends from a building drain to the public sewer; often referred to as a "service" line. (See Exhibit 10-1)
12. Lateral Sewer - A sewer that discharges into a branch or other sewer and has no other public sewer tributary to it. (See Exhibit 10-1)
13. Branch Sewer - A sewer that receives flow from a relatively small area and discharges into a main sewer serving more than one branch sewer. (See Exhibit 10-1)
14. Interceptor Sewer - A sewer which receives flow from branch sewers. (See Exhibit 10-1)
15. Outfall Sewer - A sewer which transports flow to point of treatment or final discharge. (See Exhibit 10-1)
16. Collector Sewers - A system of lateral and branch sewers.
17. Force Main - A pipe through which flow is forced by mechanical means such as a pump.
18. Gravity-Flow Sewers - A system of sewers constructed on grades or slopes so that flow will always be "downhill" and thereby flow naturally in accordance with the law of gravity.

10-3 CONSTRUCTION MATERIALS

a. Gravity-Flow Sewers

Gravity-flow sewers have been constructed over the years utilizing a wide range of pipe and joint materials. In recent years, with particular emphasis on controlling infiltration/inflow, the selection of pipe materials has become a critical factor in the construction of sewer systems. The following materials have emerged as the most common pipe materials in the construction of sanitary sewers:

1. Vitrified Clay,
2. Acrylonitrile-Butadiene-Styrene (ABS) Truss,
3. Reinforced Concrete,
4. Poly-Vinyl Chloride (PVC), and
5. Ductile Iron.

Table 10-1 lists some of the more significant characteristics and factors associated with the use of each of these pipe materials.

b. Force Mains

Force main piping from pumping stations is usually constructed using polyvinyl chloride (PVC), ductile iron, or concrete pressure pipe. PVC force mains are usually constructed of PVC Pressure Pipe which conforms to American Society for Testing Materials (ASTM) Specification D2241. Either solvent-cement or rubber gasket joints are available for PVC force mains. Nominal 20-feet laying lengths are usually provided in diameters up to 10-inches.

Ductile iron force mains are usually constructed of ductile iron pipe which conforms to the requirements of American National Standards Institute (ANSI) Specifications A21.50 and A21.51. Joints can be rubber gasket, flanged, or mechanical depending on need. Pipe diameters range from 4-inches to 54-inches and are usually available in laying lengths of 18 feet to 22 feet. Ductile iron is superior to PVC in areas where pipe strength is a critical concern.

In some instances, concrete pressure pipe is utilized for force mains. Such pipe usually meets the requirements of American Water Works Association (AWWA) Specification C301. This pipe is available in diameters from 16-inches to 144-inches and in laying lengths of 16 feet to 20 feet. Pipe joints are usually made using rubber gaskets.

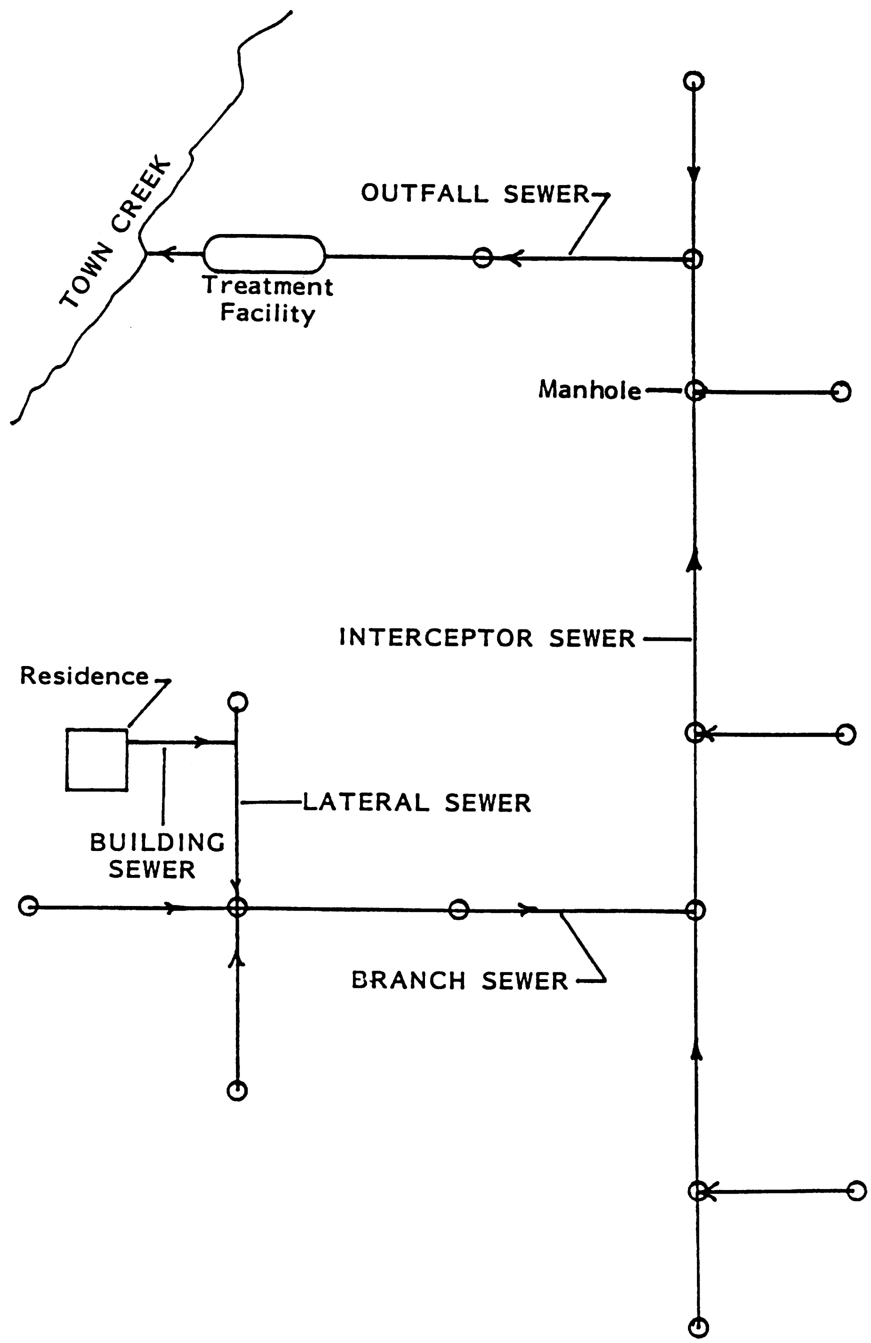

EXHIBIT 10-1

COMPONENTS OF A SANITARY SEWER SYSTEM

TABLE 10-1

CHARACTERISTICS OF COMMON SEWER PIPE MATERIALS

Pipe Material	Type Joints	ASTM Specification No.* Pipe	Joints	Installation	Common Features/Problems
1. Vitrified Clay	Compression	C700	C425	C12	Available in sizes 4” thru 36”; laying lengths vary from 4’ to 10’ depending on diameters; longevity is excellent; excellent resistance to corrosion; hydraulically smooth; excellent resistance to infiltration; material is rigid; should be handled with care during installation due to brittleness.
2. ABS Truss	Solvent-Cement	D2680	D2680	D2680	Available in sizes 8” thru 15”; laying lengths available in 6’-3” and 12’-6”; longevity is excellent; hydraulically smooth; excellent resistance to infiltration; must be bedded properly to assure strength and rigidity; light-weight & easy to handle during construction.
3. Reinforced Concrete	Rubber Gasket	C76	C443	-	Available in sizes 12” thru 144”; laying lengths vary from 3’ to 8’; highly susceptable to corrosion if not lined; highly susceptible to infiltration if not lined; common linings include bitumastic epoxy and PVC; material is rigid.
4. PVC	Rubber Gasket	D3034	F477 DF679	-	Available in sizes 4” thru 27”; laying lengths vary from 10’ to 20’; longevity is excellent; excellent resistance to infiltration; must be bedded properly to assure strength & rigidity; lightweight & easy to handle during construction.
5. Ductile Iron	Rubber Gasket	A746	A746	A746	Available in sizes 4” thru 54”; laying lengths vary from 18’ to 22’; longevity is excellent; good corrosion resistance; excellent resistance to infiltration; outside is normally coated with bitumastic; inside normally lined with cement-mortar or bitumastic; polyvinyl lining available; strength & rigidity are superior; often used at stream crossings and in traffic areas.

*NOTE: ASTM = American Society for Testing Materials.

c. Manholes

Manholes are placed in sewer systems at points of change in grade and/or direction or at intervals of about 400 feet when no grade or alignment changes are needed. Manhole construction has progressed significantly in recent years. There are three basic materials used in manhole construction today:

1. Reinforced Concrete,
2. Brick, and
3. Fiberglass.

Of these three materials, reinforced concrete is by far the most common. Brick manholes were the most common prior to the 1960's, but increased labor costs, infiltration concerns, and improved construction equipment and procedures have all but eliminated brick manholes in systems constructed today. Fiber glass units have been used only sparingly and are not yet accepted on a widespread basis. Reinforced concrete units can be either pre-cast or poured-in-place. Pre-cast units are more common due to construction costs. These manholes usually conform to the requirements of ASTM Specification C478. Pre-cast manholes are often lined with bitumastic epoxy coating to resist infiltration. Exhibit 10-2 depicts the details of a typical 48-inch diameter pre-cast concrete manhole.

Steps that are installed in a manhole should be coated with a plastic or rubber material which is corrosion resistant. Manhole castings and covers usually conform to ASTM Specification A48.

10-4 DESIGN FACTORS

The layout and design of a wastewater collection system can be influenced by several factors. In most instances, the location and capacity of a sewer are the items of greatest concern. Specific factors which are normally considered in designing a system include the following:

1. Flow Rates/Pipe Size - Flows are contributed from such sources as residences, commercial establishments, institutions, and industries. In addition, contributions can be expected from infiltration and inflow sources. It is normal practice to establish an "average daily flow" and a "peak flow." Most sewers are sized to carry peak flow while flowing 1/2 to 2/3 full. Peak flow generally averages 1.5 to 4.0 times greater than average daily flow, depending on the size of the system and population served. Average daily wastewater flows from domestic sources typically amount to 60% to 90% of water consumed. Examples of typical wastewater flows from selected domestic sources are shown in Table 10-2.
2. Pipe Slope/Velocity of Flow - Gravity sewers are normally installed at sufficient slope to produce a minimum velocity of 2 feet per second at a flow rate equal to average daily flow. Such a velocity is a "self-cleansing" rate and will help prevent solids from settling out in the pipe.
3. Location/Layout - Sewers must be located where they are needed. Such factors as required depths, property usage, easement/ROW restriction, and other utilities usually determine the specific location and routing of sewers.

10-5 INFILTRATION/INFLOW

a. Causes

It is a normal occurrence for water which is not "wastewater" to enter a sanitary sewer system. Such water is often referred to as "extraneous" water. The most common examples of extraneous water found in sanitary sewers are infiltration and inflow. Both of these terms have been defined previously in Section 10-2.

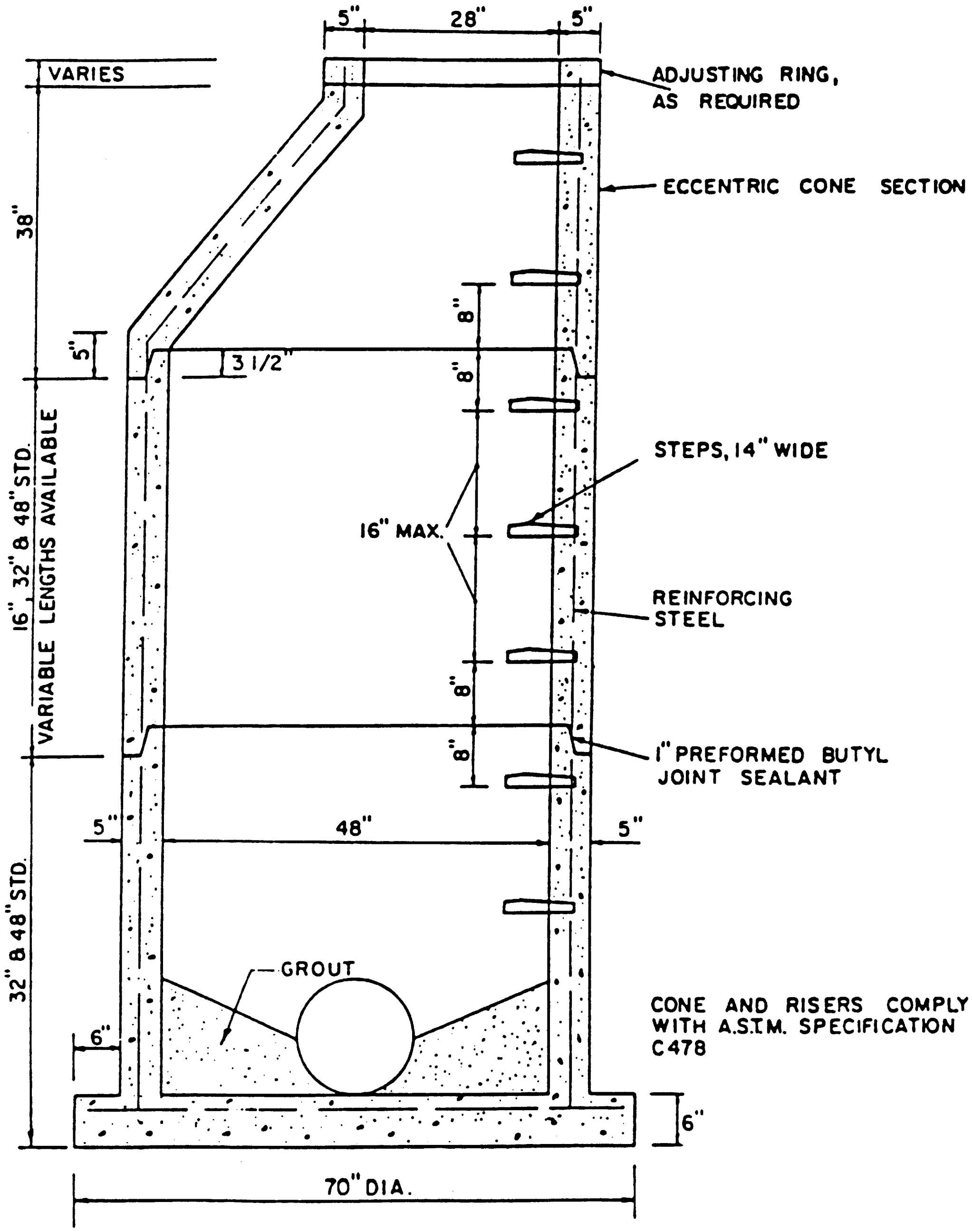

EXHIBIT 10-2

TYPICAL 48” PRE-CAST CONCRETE MANHOLE

Source: Faulkner Concrete Pipe Company Hattiesburg, Mississippi

TABLE 10-2

TYPICAL WASTEWATER FLOWS

Source	Unit	Typical Flow (Gallons/Day)	
		Range	Average
1. Residential Users			
Apartment	Person	50-90	70
Trailer Park	Person	30-50	40
Individual Residences			
Average Home	Person	50-90	75
Luxury Home	Person	80-150	100
Summer Cottage	Person	25-60	50
Rooming House	Person	25-50	40
2. Commercial Users			
Airport	Passenger	2-4	3
Automobile Service Station	Vehicle Served	8-13	10
	Employee	10-15	13
Bar	Customer	1-5	2
	Employee	10-15	13
Cafeteria	Customer	1-3	2
	Employee	8-13	10
Department Store	Restroom	400-600	500
	Employee	8-13	10
Laundromat	Machine	475-690	580
	Wash	45-55	50
Motel without Restaurant	Person	20-40	30
Motel with Restaurant	Person	50-60	55
Office Building	Employee	8-20	15
Restaurant	Meal Served	2-4	3
Shopping Center	Parking Space	0.5-2	1
Theater	Seat	2-4	3
3. Institutional Users			
Medical Hospital	Bed	130-250	170
	Employee	5-15	10
Mental Hospital	Bed	80-150	100
	Employee	5-15	10
Prison	Inmate	80-160	120
	Employee	5-15	10
Rest Home	Resident	50-120	90
	Employee	5-15	10
School (Day Students Only)			
With Cafeteria, Gym & Showers	Student	15-30	20
With Cafeteria but not Gym & Showers	Student	10-20	15
Without Cafeteria, Gym, Showers	Student	5-18	10
School (Boarding)	Student	50-100	75

Infiltration is confined to the groundwater which enters a sewer through defective joints, breaks, cracks, faulty connections, pervious materials, etc. Some of the more common factors and conditions which cause infiltration include the following:

1. Unstable soil conditions in which sewers are laid,
2. Poor quality of materials and construction,
3. High groundwater levels,
4. Root penetration into sewers,
5. Deterioration of pipe and manhole materials,
6. Improperly connected building (service) sewers, and
7. Rainfall and soil percolation rates.

Inflow is basically confined to surface water which enters a sewer from such common sources as street run-off, cross-connections with storm sewers, sink-holes over pipe or manhole breaks, flooded manhole covers, etc. Common causes of inflow problems include:

1. Cross-connections with storm sewers,
2. Connection from roof drains, yard drains, etc.,
3. Improperly connected building (service) sewers,
4. Missing or broken manhole covers,
5. Manhole tops at or below ground level in low-lying flood-prone areas,
6. Breaks in sewers at ditches and in low-lying areas,
7. Abandoned building (service) sewer connections, and
8. Inadequate drainage/stormwater collection systems.

b. Effects

As a general rule, every sanitary sewer system will receive some infiltration/inflow. In most instances, unless the quantity received is small in comparison to the quantity of "wastewater" received, problems are created within the sewer system and/or treatment facilities. Examples of common effects of significant infiltration/inflow are as follows:

1. Higher costs of power, chemicals, maintenance, etc. for pumping and/or treating the increased volume of flow,
2. Excessive wear and tear on pumping stations and treatment plant equipment, resulting in more frequent repairs and increased maintenance costs,
3. Hydraulic overloading of treatment facilities which usually results in reduced efficiencies and additional clean-up,
4. Excessive quantities of grit, soil, trash, and other debris entering sewers which in turn create additional maintenance problems,
5. Flooding of streets, properties, businesses, and residences from surcharged sewers and manholes,
6. Erosion of soil bedding around broken pipes and manholes which often lead to street and sidewalk failures,
7. Odors and health hazards resulting from by-passed, surcharged, or overflowing sewers and manholes, and

8. Prevention of property development and sewer extension due to overloaded sewers or depleted sewer capacities.

c. Analysis and Correction

Analyzing an infiltration/inflow problem as to location, quantity of water being received, and whether or not it is primarily infiltration or inflow is a most difficult task. Likewise, correcting the problem, once it has been identified, can often be difficult and expensive. A full scale approach to analyzing and correcting infiltration/inflow problems is normally carried out in a three-phase program. Such a program typically includes the following components:

1. I/I Analysis - This initial phase involves the collection and analysis of flow data to determine the actual quantity of infiltration and inflow which a sewer system receives. The flow data is collected from such sources as evaluation of available water and wastewater records and measurement of actual flows in the sewer system at selected locations under both wet- and dry-weather conditions. Once the quantity of infiltration and inflow has been determined, a decision can be made as to whether it would be more economical to try and correct the problem or to leave conditions as they exist.
2. Sewer System Evaluation Survey - If the I/I Analysis shows that the quantity of infiltration and/or inflow is such that it would be more economical to correct conditions, a Sewer System Evaluation Survey is begun. This second-phase program basically involves detailed evaluation of the suspected problem areas in a sewer system for the purpose of establishing specific repair needs. During this phase, such procedures as smoke testing and television inspection are conducted on suspected reaches of sewers. From this work, detailed cost estimates of replacing and/or repairing sewers can be prepared.
3. Rehabilitation/Replacement - This third and final phase simply involves replacing sewers with new materials where needed and/or rehabilitating the system with such procedures as grouting, sliplining, installing water-tight covers, raising manholes, etc.

Unfortunately a full-scale program as outlined above can be an expensive undertaking and usually is not done unless financial assistance is available to a community through government loans and grants. When funding is not available for a full-scale program as outlined, there are several relatively inexpensive things which can be done to reduce infiltration/inflow problems:

1. Visual inspection of sewers to detect major problems,
2. Smoke testing selected reaches of sewer,
3. Repair all known breaks in sewers and manholes,
4. Pass and enforce sewer use ordinance that makes it illegal to connect yard drains, roof drains, etc. to sanitary sewers,
5. Inspect all new additions and extensions to sanitary sewers to be certain that proper pipe materials and construction procedures are used,
6. Inspect all new building (service) sewer connections to be certain a watertight connection is made,
7. Raise manhole tops in low-lying areas, and
8. Utilize water-tight manhole covers or use nuts and bolts to plug vent holes on manhole covers in flood-prone areas.

d. Prevention

The task of preventing major infiltration/inflow problems in sanitary sewer systems is generally more effective and less expensive than correcting the problems. Most preventive measures must be taken in the planning and design stage of a project before the system is constructed. Factors which are commonly considered by engineers and community officials to prevent significant infiltration/inflow in a sewer system to be constructed include the following:

1. Pre-Design Investigation - Such factors as soil conditions, groundwater levels, location of flood-prone areas, high water elevation, rainfall, problems with existing systems in the area, etc. should be investigated. The information compiled can be used in routing sewers away from known problem areas or in designing sewers in problem areas to handle a sufficient volume of flow.
2. Selection of Pipe Materials - A rigid specification which requires impervious pipe material, water-tight joints, suitable bedding material, and proper construction procedures should be strictly enforced.
3. Design Allowance - Realizing that every system is going to experience some infiltration/inflow problems, it is reasonable to include an allowance for infiltration/inflow in design flows so that pipe sizes will be adequate.
4. Construction Inspection - Thorough and competent inspection of the construction of the sewers should be provided to be sure that the specifications are followed.
5. Building Sewer Connections - A connection to the public sewer should not be allowed until the building (service) sewer connection has been inspected and approved.
6. Sewer Use Ordinance - A sewer use ordinance should be adopted and enforced which includes restrictions on the connections of yard drains, roof drains, storm drains, etc.

10-6 OPERATION AND MAINTENANCE

a. Objectives & Goals

A sanitary sewer system is intended to meet the needs of its users in a safe, efficient, and economical manner. If it is to do so, then sound operation and maintenance principles must be practiced. Some of the principles which should be included in the goals and objectives of a properly managed wastewater collection system include:

1. Continuous and routine inspection of system for physical damage,
2. Prompt repair of damages and elimination of the cause of such damage,
3. Organized plan of routine preventive maintenance,
4. Prompt investigation of all complaints,
5. Promote and practice a sound safety program,
6. Require courteous and efficient performances by all personnel,
7. Strict enforcement of sewer use ordinance,
8. Maintenance of accurate and up-to-date sewer map, and
9. Require all new construction to comply with ordinance.

An operation and maintenance system based on these principles will minimize interruption of service and will protect a community’s financial investment in the system.

b. Common O & M Problems

The problems experienced in the operation and maintenance of a sanitary sewer system can vary from routine to unusual. Some of the more common problems which occur include:

1. Crushed, broken, cracked, or misaligned pipe from such causes as shifting soil, heavy traffic loads, improper bedding, roots, etc.,

2. Faulty building (service) sewer connections,
3. Sand and grit deposits from street run-off, yard drains, and other inflow sources,
4. Odors, hydrogen sulfide gas, and clogging from settleable deposits due to low velocities caused by inadequate grades, low flows, or flow restrictions,
5. Accumulation of grease,
6. Accumulation of trash, debris, toxic or flammable materials, and other substances improperly placed in sewer,
7. Surcharged and overflowing manholes and "back-ups" due to hydraulic overloads and/or clogged pipes,
8. Root penetration through joints and cracks,
9. Dislocated manhole frames and covers,
10. Excessive infiltration and/or inflow, and
11. Mechanical and electrical problems with pumping stations.

c. System Maintenance

Maintaining a sanitary sewer system involves the use of people, equipment, and materials. As with any utility system, maintenance can be grouped into preventive and corrective practices. As a general rule, less corrective action is required when more preventive action is taken. The amount of preventive maintenance which a community provides is usually determined by available manpower and budget resources.

A successful maintenance program will include both preventive and corrective measures. Some components of a successful maintenance program will likely include most of the following activities:

1. Routine Inspection and Surveillance - A regular program of inspecting a system to look for problems or potential problems will go a long way toward preventing "major" problems. Inspections can range from a simple surface inspection to a thorough closed-circuit television inspection. The specific degree of inspection is usually determined according to a system's size, the manpower available, and costs. As a general rule, however, physical inspection at manholes can be provided with minimal cost and manpower. Such inspections will normally reveal a lot of useful information about the condition of a system. Things to look for during manhole inspections include structural integrity of pipe and manholes, signs of surcharging, grit deposits, pipe connections at manhole, leaks in pipes or manholes, condition of frame and cover, elevation of manhole top relative to surrounding terrain, etc.
2. Smoke Testing - Smoke testing as a routine measure or in areas where serious inflow is suspected is a relatively inexpensive means of locating serious openings in a sewer system.
3. Cleaning - Cleaning can be routinely scheduled or practiced as needed to prevent and remove pipe blockages. Methods available include rodding, balling, flushing, jetting, and mechanical bucket. In most smaller communities, cleaning is contracted out to private contractors.
4. Minor Repairs - Repairs are usually made by local personnel on such items as manhole repair, adjustment of castings, and replacement of collapsed or broken pipes where small-scale excavations are required.
5. Major Repairs - Repairs which are beyond the scope of a community's personnel should be contracted out to a qualified contractor. The community must insure that its requirements for materials and construction are fully complied with by providing competent inspection.
6. Chemical Dosing - In areas where grease, root penetration, and odors are major problems, chemical dosing can be an effective preventive or corrective measure. However, such practice should not be carried out until the proper chemical has been selected and approved by responsible persons with professional expertise.

7. Flow Measurements - Flow records of some degree should be kept in a community; usually as required by the NPDES permit issued for the treatment facility. These records or additional records should be continuously reviewed and monitored for the purpose of establishing “normal” flow patterns and detecting “abnormal” flows which could indicate problems.

10-7 PUMPING STATIONS

Pumping stations are a common component in many sanitary sewer systems. They are normally used in locations where depth and/or grade problems make it more economical and practical to pump the wastewater rather than utilize gravity flow. Chapter 11 addresses pumping systems specifically.

CHAPTER 11

WASTEWATER PUMPING

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CHAPTER 11

WASTEWATER PUMPING

11-1 ROLE OF PUMPS IN WASTEWATER COLLECTION & TREATMENT

Pumps are used as an alternative to gravity flow in transporting liquids from one point to another. As a general rule, pumping is used only when it is more economical than providing a gravity flow system or when physical restrictions prevent the use of a gravity flow system. Ideally, a sanitary sewer system should be designed so that as much of the wastewater as possible will flow by gravity to a treatment facility and thence continue flowing through the treatment works by gravity. However, in reality, such ideal conditions are rarely possible throughout a system. In many communities, there are isolated low-lying areas from which the wastewater must be pumped into the main sewers; or there may be flat terrain where it is simply more economical to pump the wastewater rather than construct deep sewers. Often, location of a treatment facility is determined more by availability of land than natural terrain features and, as a result, it is not always feasible to achieve gravity-flow conditions to or through the facility. In such cases, pumps are used to achieve mechanically what it is not practical or economical to allow the natural force of gravity to do.

Pumps are used for a variety of functions in wastewater collection and treatment systems. Most applications, however, can be categorized as either "raw wastewater" pumping or "process" pumping. Raw wastewater pumping involves the use of pumping stations which, along with gravity sewers, comprise a community's sanitary sewer system. Process pumping involves the use of pumps as components in a treatment facility.

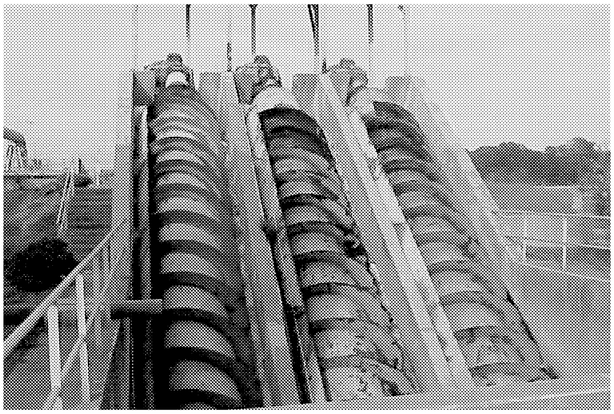
For each type of pumping application, there are various types of pumps and accessories which can be selected to provide the desired service. The actual selection of a pump for a particular use involves the evaluation of several factors which will influence the performance of the pump once it is installed. These factors include such items as the characteristics of the liquid being pumped, the rate of flow which must be handled by the pump, and the physical conditions under which a pump must perform. Pump selection is primarily an engineering matter which is considered to be beyond the scope of this manual and therefore, will not be addressed herein.

Exhibit 11-1 shows examples of various wastewater pumping facilities in use in Mississippi.

11-2 TYPES OF PUMPS

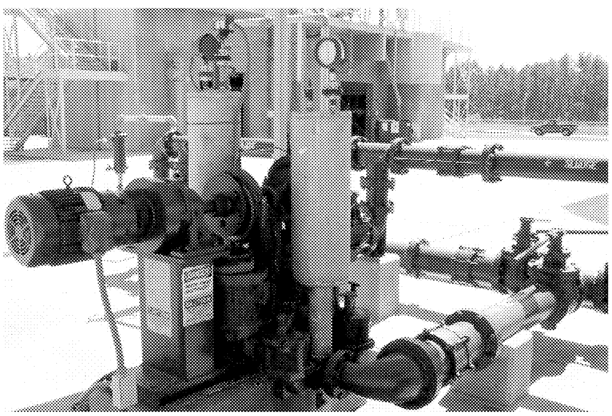
a. General

Classification of pumps into various types is often a confusing matter. Persons in one field will frequently refer to a particular type of pump; while persons in another field will refer to the same type of pump with different terminology. Pumps are often classified or referred to by manufacturers, engineers, or pump-owners in various terms with which they are familiar. With regard to the field of wastewater collection and treatment, pumps commonly used can be separated into three (3) basic types:



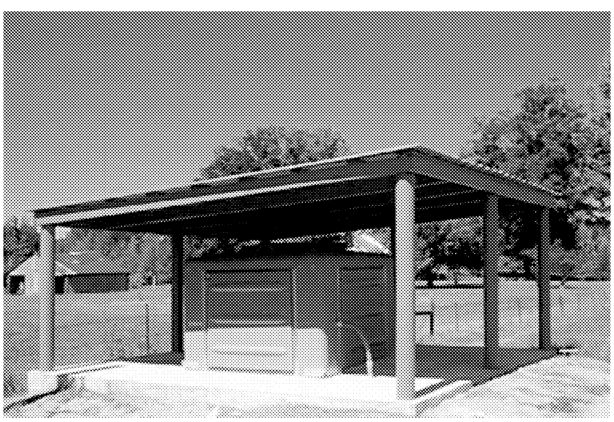
INCLINED SCREW INFLUENT PUMPS

CENTRFUGAL EFFLUENT PUMPS



PISTON SLUDGE PUMP

CENTRIFUGAL RETURN SLUDGE PUMPS



WET WELL MOUNTED PUMP STATION

SUBMERSIBLE PUMP STATION

EXHIBIT 11-1

PUMPING FACILITIES IN MISSISSIPPI

1. Centrifugal,
2. Positive-displacement, and
3. Pneumatic.

There are various pumps within each of these basic types with particular features and details which result in more specific terminology being applied to each pump. For example, centrifugal pumps include pumps commonly referred to as submersible pumps, vertical or horizontal pumps, suction pumps, etc. Therefore, too much emphasis should not be placed on whether or not a pump is properly classified. As long as a pump's features and capabilities are understood by the pump selector and the pump owner, it should not matter greatly by what name the pump is classified.

b. Centrifugal Pumps

Centrifugal pumps are probably the most common type of pump used in wastewater collection and treatment systems. Each centrifugal pump has two (2) main parts which combine to create a "centrifugal force" that moves the liquid through the pump. These two (2) components are the impeller and the pump casing. The impeller is a rotating element inside the casing. As the impeller rotates, the rotating motion draws the liquid being pumped through an inlet opening and, by means of centrifugal force, throws out or "discharges" the liquid through an outlet opening. The impeller is mounted on a shaft supported by bearings and is rotated by a motor drive. Rotation of the impeller causes the liquid to leave the pump at a higher pressure (head) and velocity than when it entered.

Pump casings are close-fitted around the impeller. They can be either "volute" casings or "diffusion" casings. A volute casing is one in which the channel surrounding the impeller increases gradually to the size of the pump's discharge. A diffusion casing is one in which the impeller discharges into a channel which has guide vanes which serve to "diffuse" the discharged liquid. Pumps with diffusion casings are often referred to as "turbine" pumps. Most centrifugal pumps used in wastewater applications have volute casings because more clogging problems are encountered with the vanes in a diffusion casing. Treated wastewater effluent is sometimes pumped with diffusion casing pumps because the suspended matter which would tend to cause clogging has been removed.

The most common centrifugal pumps used in wastewater applications include suction pumps, positive-prime or flooded-suction pumps, and submersible pumps.

c. Positive-Displacement Pumps

As the name implies, positive-displacement pumps move or "displace" a definite or "positive" volume of liquid with each cycle of the pumping mechanism. Positive displacement pumps generally have two (2) key features which distinguish them from centrifugal pumps. First, they can pump large solids without clogging and, secondly, they can operate efficiently at a constant speed over a wide range of flows. Examples of positive-displacement pumps commonly used in wastewater applications include "plunger" or "piston" pumps and "screw" pumps. In a plunger pump, a plunger or piston moves back and forth inside the pump and alternately lifts the liquid (on the suction stroke) and discharges it (on the delivery stroke). Plunger pumps have traditionally been used for pumping sludge at wastewater treatment plants. Screw pumps are perhaps the oldest type of pump known to man; but they have not been widely used in wastewater applications until recently. A screw pump operates on the basis of a revolving shaft fitted with helical blades which rotates in an inclined trough and pushes the liquid up the trough. Screw pumps are commonly used in wastewater treatment facilities for such purposes as low-lift pumping of untreated wastewater, sludge pumping, and effluent pumping.

d. Pneumatic Pumps

Pneumatic pumps are air-operated and have no internal moving parts. The most common types of pneumatic pumps found in wastewater applications are ejectors and air lifts. Ejectors consist of a casing or vessel into which the liquid flows or is drawn by suction. When the vessel is full, the contents are ejected by compressed air. The use of ejectors in wastewater systems is usually confined to raw sewage pumping stations serving isolated locations which have very low flows. Air-lifts consist of two vertical pipes - a small diameter air supply line inside a larger diameter riser pipe. Air is forced through the supply line and as it leaves the bottom of the smaller line, it expands and forces the liquid in the riser pipe upward. Such systems are commonly used in wastewater treatment facilities for transferring sludges.

11-3 RAW WASTEWATER PUMPING STATIONS

Many, if not most, sanitary sewer systems contain one or more pumping stations. Pumping Stations may vary in certain details, but generally contain the same basic components, which include the following:

1. Pumps - Usually two or more centrifugal pumps are provided. (A station with two (2) pumps is called a "duplex" station; one with three(3) pumps is a "triplex"; one with four(4) pumps is a "quadraplex," etc.)
2. Wet Well - The wastewater flows to a concrete or steel basin from which it is removed by the pumps.
3. Controls/Alarms - Pumps are usually turned off and on by automatic controls which are activated as the level of wastewater in the wet well rises and falls. If a pump fails to operate, the wastewater level rises in the wet well and activates an alarm (light, bell or horn) to notify the person in charge. The most common types of controls include sealed floats and bubbler systems.
4. Valving/Piping - A system of pipes and valves are normally installed at a pump station. When suction pumps are used, suction piping is necessary through which the wastewater is drawn from the wet well. Discharge piping normally consists of a gate or plug valve and a check valve on the discharge line from each pump. The discharge pipes from multiple pumps are usually joined into a single force main immediately downstream of the valving.

Perhaps the major difference in pumping stations normally encountered in sanitary sewer systems lies with the particular type pump selected and the manner in which it is located with regard to the wet well. Except for small ejector stations, which utilize pneumatic pumps, the vast majority of raw wastewater pumping stations utilize some type of centrifugal pump. The installation of these centrifugal pumps relative to the wet well generally falls into one of three categories:

1. Submersible Station - Submersible pumps are installed directly in the bottom of the wet well. The pumps are manufactured to operate submerged in the wastewater; therefore, the wastewater is drawn directly into the pump and discharged through the valving and force main.
2. Wet-Well Mounted Station - Suction pumps are mounted over the wet well and the pumps suck the wastewater from the wet well and discharge it through the valving and force main. Suction pumps generally are either constructed to maintain their own prime ("self-priming") or are primed by a separate small vacuum pump which fills the pump ("vacuum-priming").
3. Wet Pit/Dry Pit Station - The pumps are installed in the bottom of the dry pit which is located adjacent to the wet pit (wet well). The two pits are connected by piping at the bottom. The wastewater level in the wet pit creates a "positive head" or "flooded suction" on the piping which serves as the pump

inlet. Consequently, no lifting of the wastewater is required as it is with wet-well mounted stations. The pumps simply discharge the wastewater by drawing it from the wet well and pumping it through the valving and force main.

Exhibits 11-2, 11-3, and 11-4 illustrate each of these types of pumping stations.

11-4 ANALYSIS OF PUMPING SYSTEMS

a. Pump Capacities

The capacity of a pump is the flowrate at which that pump discharges. More specifically, it is the volume of liquid which is pumped per unit of time. It is common practice to express capacity in units of "gallons per minute" (GPM) or "million gallons per day" (MGD).

b. Head

The term head is simply a measure of the pressure on a given point. Rather than being expressed in terms of "pounds per square inch" (psi) or other units often associated with pressure, head is usually expressed as the equivalent depth (feet) of water on the point in question. This expression is based on the following equation:

Head (feet of H_2O) = Pressure (psi) x 2.31

The basis for this equation is that a column of water 2.31 feet in height and 1-inch by 1-inch in cross-sectional area weighs 1 pound.

In analyzing pumping systems, head is generally applied to the pumps and the pumping system, which includes force main piping, valves, etc. Pump head is the height which a pump can raise the liquid being pumped. System head is the head against which a pump or pumps must work to overcome the resistance to flow in the valving and piping in order to produce a specific capacity or flowrate. Usually the pump head is determined for each pump through tests conducted by the manufacturer. This head is generally shown on a "pump curve" provided by the pump manufacturer. The curve shows the pump's capacity (GPM) at various heads, for different size impellers. Also, it is common to show horsepower requirements and efficiency on the curve. Exhibit 11-5 shows a typical pump curve.

A system head must be determined through computations knowing certain data about the pumping system. The system head is usually expressed in terms of the "total dynamic head" (TDH) at various flowrates. TDH is the head against which a pump must work when the liquid is being pumped. For most practical applications, TDH can be computed as follows:

TDH = Static Head + Friction Head + Station Head where,

T D H = total dynamic head (feet)

Static Head = difference in elevation between the discharge liquid level and the liquid level in the wet well,

Friction Head = the head of water which must be supplied to overcome the frictional loss caused by the flow of liquid through the piping system, and

Station Head = the head of water which must be supplied to overcome the loss of head through fittings and valves in the pump station.

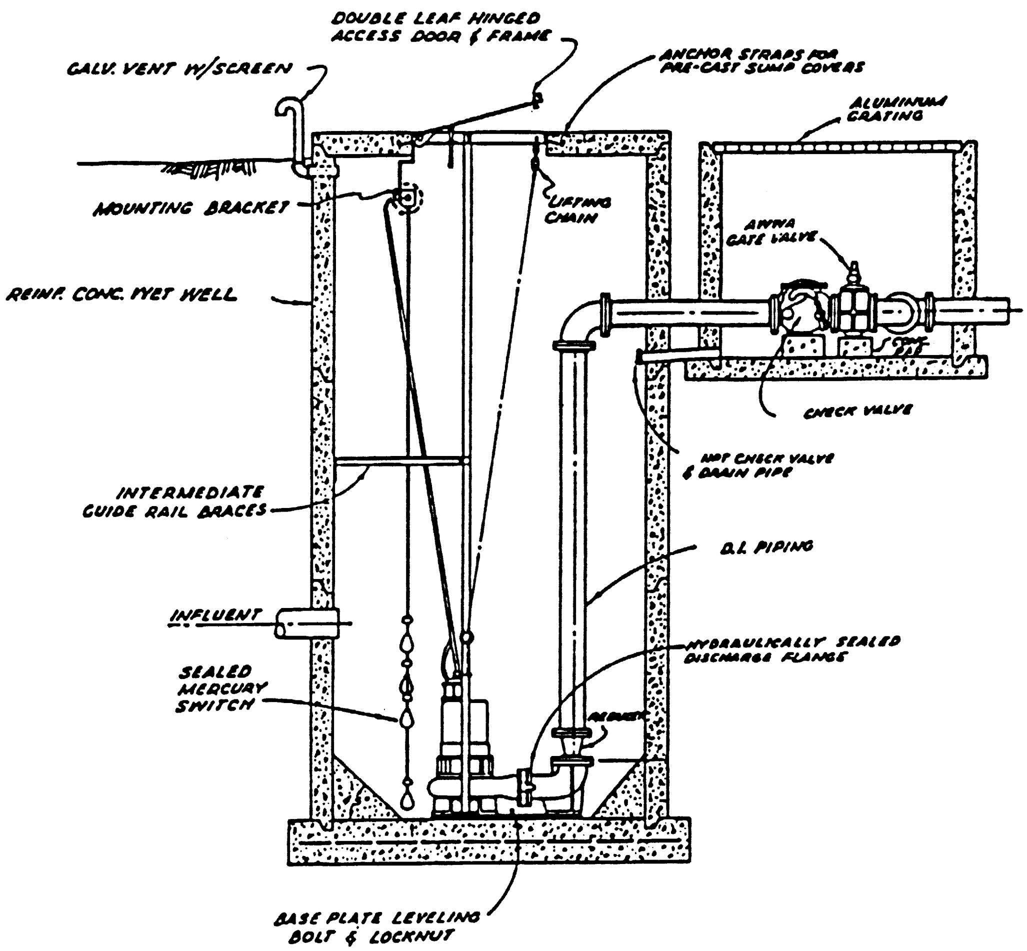


EXHIBIT 11-2

TYPICAL SUBMERSIBLE PUMPING STATION

Source: Hydro-O-Matic Pumps, Ashland, Ohio

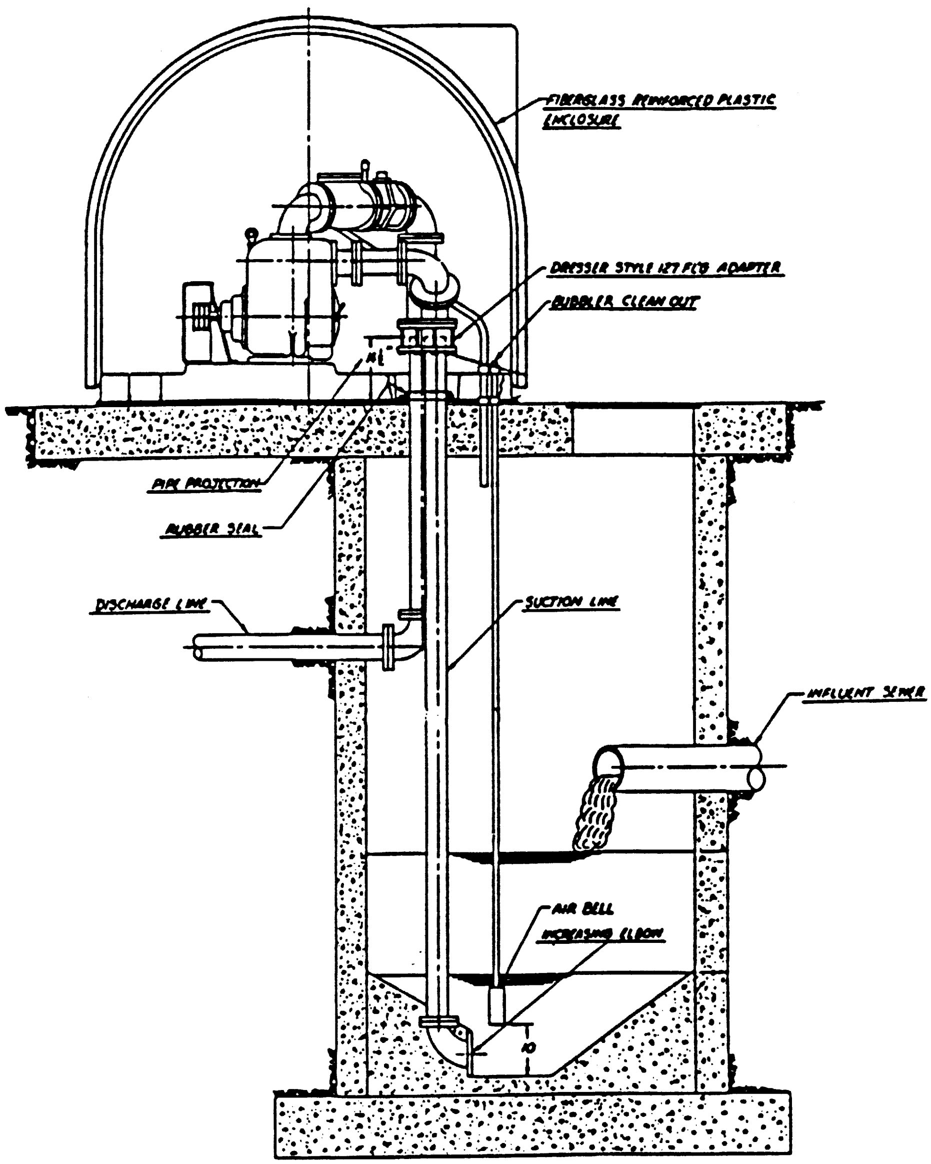


EXHIBIT 11-3

TYPICAL WET WELL MOUNTED PUMPING STATION

Source: Gorman-Rupp Company, Mansfield, Ohio

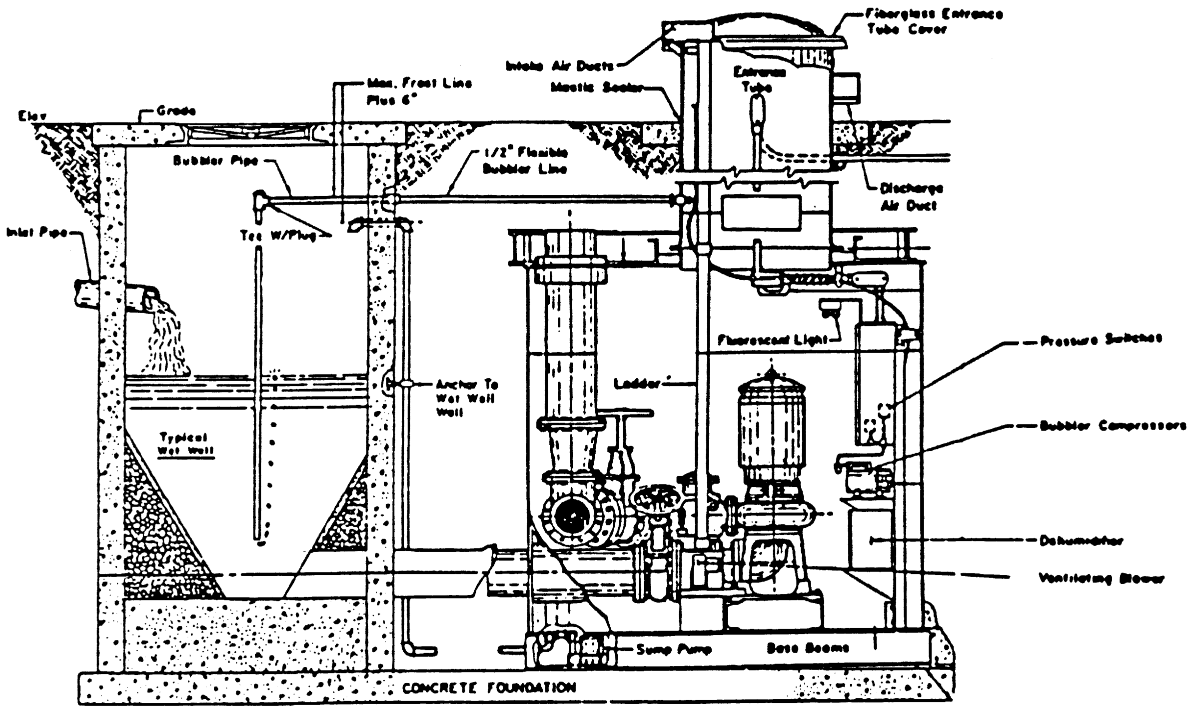


EXHIBIT 11-4

TYPICAL WET PIT/DRY PIT PUMPING STATION

Source: Smith and Loveless, Lenexa, Kansas

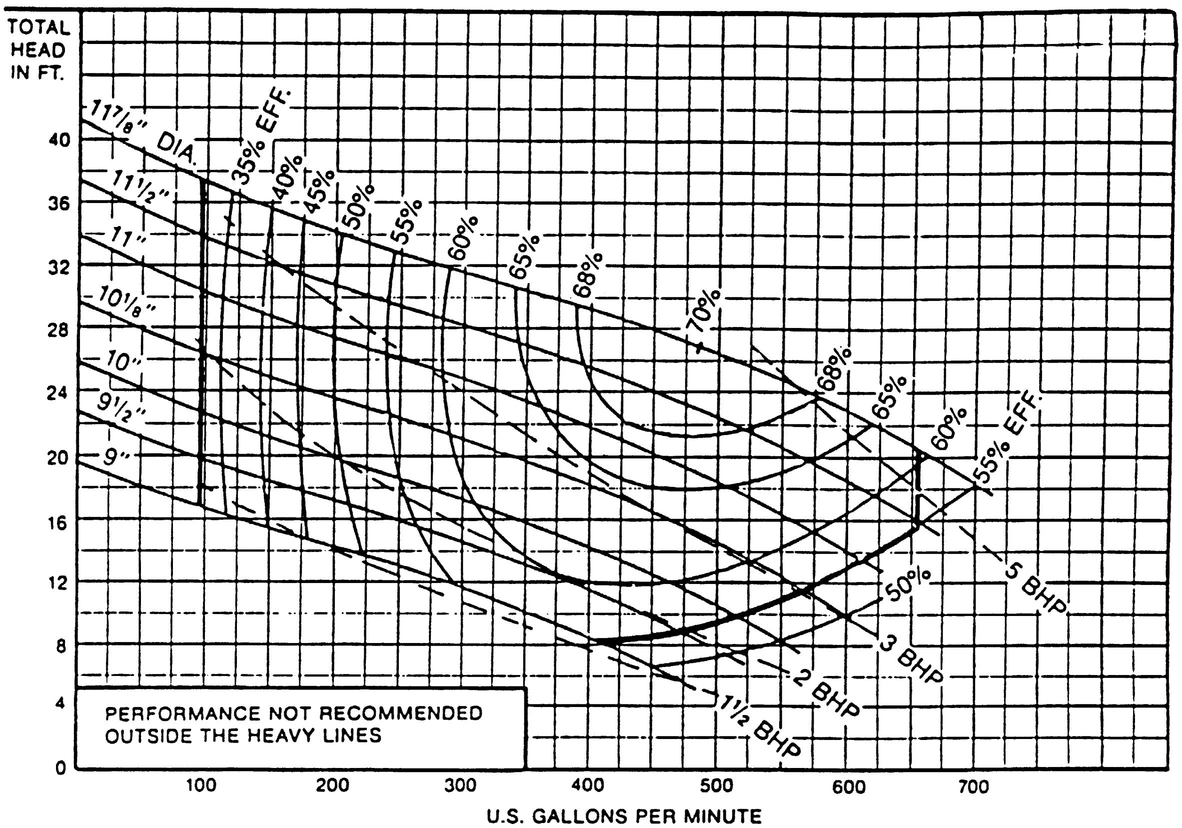


EXHIBIT 11-5

TYPICAL PUMP CURVE

Source: Hydr-O-Matic Pumps, Ashland, Ohio

c. Pump Efficiency

The efficiency at which a pump operates is usually expressed as a ratio of output power of the pump to the input power. This efficiency can be computed as follows:

$$Ep = \frac{\text{Pump Output}}{\text{Brake Horsepower}} = \frac{\gamma\, Q\, H}{BHP \times 550}$$

where,

Ep = Pump Efficiency

γ = Specific Weight of Water (lbs/CF)

Q = Pump Capacity (CF/sec)

H = Total Dynamic Head (feet)

BHP = Brake Horsepower Rating of Pump

550 = Conversion Factor for HP to ft-lbs/sec

Pump efficiencies for wastewater pumps usually, at best, are in the range of 60 to 85 percent. This means that energy losses of 15 to 40 percent are experienced in the operation of the pumps.

11-5 CARE AND MAINTENANCE OF FACILITIES

Pumps are no different than any other mechanical equipment. They need proper care and maintenance if they are to perform in an efficient and reliable manner. Every pump has a recommended maintenance practice for both preventive and corrective measures as set forth by the manufacturer. Such recommended practices have a purpose, which is to maximize the life and use of the pumps. The manufacturer's recommendations for maintenance should be followed in a systematic and regular manner.

CHAPTER 12

RECORDS AND REPORTS

* * * * *

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CHAPTER 12

RECORDS AND REPORTS

12-1 IMPORTANCE OF RECORDS

The need for keeping thorough and accurate records can not be over-emphasized. A thorough record keeping system usually indicates an efficient and well-operated sewer system and treatment facility. In general, records are needed for the following basic reasons:

1. Review of operating records can indicate the efficiency of the overall treatment facility and its individual components.
2. Records can help in the evaluation of past problems and the subsequent prevention of future problems.
3. Records are needed to show type and frequency of maintenance and to evaluate the effectiveness of maintenance programs.
4. Records can provide data upon which to base recommendations for modifying or expanding system operations and facilities.
5. Records of past performance and operational procedures are invaluable in evaluating present performance and can serve as a basis for the design of future units.
6. Records are used to support budget requests for additional personnel, facilities, equipment, or supplies.
7. Records may be needed in law suits or enforcement proceedings.
8. Records provide the data for preparation of reports to regulatory agencies such as the Office of Pollution Control and the U.S. Environmental Protection Agency.

Records should be kept in a permanent, complete, accurate, and neat manner. Ink should be used for all hand-written entries. A lead pencil should not be used because notations can smudge and be altered or erased. False and misleading records may actually do more harm than not having any records at all. Records should always be filed in a manner that will provide easy access by authorized personnel. A record misfiled is a record lost and a lost record is worthless. A designated filing area is essential for safe and efficient storage of records.

Records can generally be grouped into the following major categories:

1. Physical Plant Records,
2. Operation/Performance Records,
3. Maintenance Records,
4. Personnel Records, and
5. Budget/Operating Expenses.

12-2 PHYSICAL PLANT RECORDS

Records which describe and illustrate the physical details of a sewer system and treatment facility should be maintained. Such records should include the following:

1. "As-built" plans and specifications of sewers, pumping stations, and treatment facilities;
2. Operation and maintenance manuals prepared specifically for system and facilities being operated;

3. Shop drawings and manufacturer's literature on installation, operation and maintenance for all equipment;
4. Hydraulic profile which shows operating water elevations in all treatment units;
5. Equipment record which shows equipment name, manufacturer, identification numbers, rated capacity, and dates of purchase and installation; and
6. Itemized costs and quantities for all major facilities.

As with all records, physical plant records must be kept in a safe and permanent manner so that they will be accessible when needed.

12-3 OPERATION/PERFORMANCE RECORDS

a. General

For each sewer system and wastewater treatment system, data on operation and performance should be collected, analyzed and reported. Records of such data should be compiled based on the particular needs and conditions which exist. Each record should have a purpose - no record should be kept just for the sake of keeping a record. Each piece of data and information should be recorded with a specific purpose in mind. Records should be kept of any activity which is pertinent to the operation, management, and maintenance of a sewer system or treatment facility.

b. Daily Records

A daily record of activities pertinent to the operation and performance of a sewer system and treatment facility should be kept. Usually such information is initially recorded in a "daily diary." Examples of the type information which typically is recorded in a diary include the following:

1. Date and day of week;
2. Weather information such as rainfall, temperature, storm events, etc.;
3. Progress of construction or maintenance work;
4. Failure of a piece of equipment;
5. Accidents to personnel;
6. Description of any unusual or special events such as by-passes, complaints, inspections, etc.;
7. Names and affiliations of visitors;
8. Pertinent equipment settings and readings such as flow-recorder readings and chlorine feed rate;
9. Results of any field testing such as temperature, pH, dissolved oxygen, chlorine residual, etc; and
10. Pertinent information on purchasing of supplies and equipment.

It is suggested that a daily diary be kept in a bound notebook which the person keeping the record has with him at all times. The information kept in the diary can thence be transferred on a regular basis to a permanent daily log which can be conveniently placed in a file. Exhibit 12-1 is an example of a permanent daily log which could be kept on file at a wastewater treatment facility.

EXHIBIT 12-1

EXAMPLE DAILY LOG

CLEANWATER, MISSISSIPPI

WASTEWATER TREATMENT PLANT

* * * * *

DATE: ______________ ______________ ______________ S M T W T F S

(Month) (Day) (Year) (Day of Week)

WEATHER OBSERVATIONS

Temperature: ____________ ° ____________ @ ________________ O'Clock ______

Rainfall: ____________ Inches (Gauge Reading @ ________________ O'Clock) ______

General Conditions: ____

Unusual Events: ____

FIELD TESTS

	Time of Day	Temp. (C°)	pH (Std. Units)	D.O. (mg/l)	Cl_2 (mg/l)	30-Minute Settleability (ml/l)
Influent						
Aeration Tank						
Clarifier						
Effluent						

FLOW

Totalizer Reading @ ________________ = ________________________

Totalizer Reading Previous Day = ________________________________

Average Daily Flow ________________ MGD; Peak Flow Rate ______________ MGD

MISCELLANEOUS

Return Sludge ____

Waste Sludge ____

Chlorine Feed Rate ____

Remarks ____

____

____

____

Operator

EXHIBIT 12-2

EXAMPLE LAB FORM FOR BOD TEST

* * * * *

CLEANWATER, MISSISSIPPI

WASTEWATER TREATMENT PLANT

* * * * *

5-DAY BIOCHEMICAL OXYGEN DEMAND (20˚C)

SAMPLE DATE ______________ TYPE SAMPLE ______________ TEST DATE ______________ ANALYST ______________

Sample Source															
Bottle No.															
Percent Dilution															
Date Off															
Initial D.O. (mg/l)															
Final D.O. (mg/l)															
Actual D.O. Depletion															
Blank Depletion															
Corrected Depletion															
Dilution Factor															
BOD (mg/l)															

Remarks:

EXHIBIT 12-3

EXAMPLE LAB FORM FOR SUSPENDED SOLIDS TEST

* * * * *

CLEANWATER, MISSISSIPPI

WASTEWATER TREATMENT PLANT

* * * * *

TOTAL SUSPENDED SOLID AND VOLATILE SUSPENDED SOLIDS

SAMPLE DATE __________________ TYPE SAMPLE __________________ TEST DATE __________________

Sample Source								
1. Volume of Sample (ml)								
Tare No.								
2. Wt. Filter + TSS (gms) @ 103˚C								
3. Wt. Filter (gms)								
4. Wt. TSS (gms) = 2 - 3								
TSS (mg/l) = 4/1 x 1,000,000								
5. Wt. filter + TSS After 560˚C (gms)								
6. Wt. VSS (gms) = 2-5								
VSS (mg/l) = 6/1 x 1,000,000								
% Volatile								

Analyst____

EXHIBIT 12-4

EXAMPLE LAB FORM FOR TKN OR AMMONIA-N TEST

* * * * *

CLEANWATER, MISSISSIPPI

WASTEWATER TREATMENT FACILITY

* * * * *

SAMPLE SOURCE ______________________________ TYPE SAMPLE ________________

DATE OF SAMPLE______________________________ TEST DATE ANALYST __________

Sample No.	Aliquot	Titration		ml Titrant	-Blank	Factor	mg/l
		Final	Initial				

Remarks:

EXHIBIT 12-5

EXAMPLE LAB FORM FOR FECAL COLIFORM TEST

* * * * *

CLEANWATER, MISSISSIPPI

WASTEWATER TREATMENT FACILITY

* * * * *

FECAL COLIFORM COUNT

(Membrane Filter Procedure)

SAMPLE SOURCE: ______________________________

SAMPLE COLLECTED: ______________ O'CLOCK AM/PM; DATE: ______________

SAMPLE CONDITIONS: TEMPERATURE __________ : Cl_2 RESIDUAL ________ ; pH ________

INCUBATION: IN ______________ O'CLOCK AM/PM; DATE: ______________

OUT ______________ O'CLOCK AM/PM; DATE: ______________

ANALYST ______________________________

SAMPLE NUMBER	DILUTIONS									COLONIES/100ml

REMARKS:

c. Laboratory Records

The collection of samples and conducting laboratory tests on those samples are necessary for the proper operation of a wastewater treatment facility. Data should be compiled from laboratory tests that are necessary to control treatment processes and evaluate performance. If the data compiled from laboratory tests is to be used for its intended purpose, accurate records must be kept in a neat orderly manner.

The most practical way of maintaining good laboratory records is to prepare convenient forms on which data can be easily recorded. These forms should be prepared to fit the particular need of each individual plant. It is suggested that these lab forms be kept in a ring binder notebook or similar device to prevent destruction. Periodically, such as at the end of each month, the forms can be removed from the notebook and placed in a permanent file. Exhibits 12-2 through 12-5 illustrate example lab forms for the more common laboratory tests required (BOD, Suspended Solids, Total Kjeldahl or Ammonia Nitrogen and Fecal Coliform).

d. Monthly Performance Reports

A monthly performance summary for a treatment facility should be maintained. Information recorded in such a report is helpful in reviewing performance characteristics and trends. The information which should be recorded on a monthly report will vary according to the type treatment facility, but generally should include such things as data from the daily log, laboratory results, calculated operating parameters, and removal efficiencies.

The monthly reports should be kept on printed forms and filed in a neat orderly manner so that they will be easily available for such purposes as agency inspections, completion of NPDES Discharge Monitoring Reports, and general review of performance efficiencies.

Exhibits 12-6 through 12-9 are examples of monthly performance reports or "logs" which could be used for activated sludge, trickling filter, lagoon, and anaerobic digester facilities respectively.

e. NPDES Discharge Monitoring Reports

Both publicly-owned and privately-owned wastewater facilities in Mississippi are operated under conditions set forth in a National Pollutant Discharge Elimination System (NPDES) permit. The owner of the treatment facility is required to submit a "Discharge Monitoring Report" once a quarter to the Office of Pollution Control. Facilities which are classified as "major" by the Office of Pollution Control are presently required to submit reports on a monthly basis, whereas facilities classified otherwise are required to submit on a quarterly basis. This report will show the results of laboratory and field tests and the calculation of operating parameters required by the NPDES permit. The purpose of the report is to show whether or not the treatment facility has complied with its permit conditions.

Exhibit 12-10 is an example of a completed Discharge Monitoring Report. Comments and instructions regarding completion of the report are as follows:

1. Permittee Name/Address - The name and address of the entity to whom the NPDES permit is issued should be shown along with the name and location of the treatment facility for which the permit is issued. Usually, this information is contained on the printed report forms furnished to each permit holder by the Office of Pollution Control.
2. Permit Number/Discharge Number/Monitoring Period - The NPDES permit number of the facility addressed by the report should be shown in the designated space. The discharge number defines which

discharge point is represented by the NPDES permit number and report. In most cases, a permittee only has one discharge point; hence, the number is usually reported as "001" in such instances. If a permittee has more than one point of discharge, the discharge number could be "002", "003", etc. as the case may be. The monitoring period refers to the period for which the report is applicable. Usually, this period is monthly or quarterly. All of the aforementioned information is usually contained on the printed forms furnished by the Office of Pollution Control to each permit holder.

3. Parameter - The column entitled "Parameter" should contain the various parameters shown in the NPDES permit which are required thereby to be reported. Said information is usually printed on the report forms furnished by the Office of Pollution Control.

4. Quantity or Loading - When applicable, this dual-column information is usually expressed in units of "Pounds/Day" (Lbs./Day) or "Million Gallons/Day" (MGD). The column designated "Average" is for the monthly or quarterly average of each parameter. The column entitled "Maximum" is for maximum weekly averages of each parameter. The horizontal column entitled "Permit Requirement" should contain the average (monthly or quarterly) and maximum weekly average allowed by the NPDES permit when applicable. Such information will usually be printed on the report forms furnished by the Office of Pollution Control. The horizontal column entitled "Sample Measurement" should show results computed from the actual sampling/testing conducted during the monitoring period. Computation of "Lbs/Day" for each parameter should be based upon the flow (MGD) for the date of the sample and the concentration (mg/l) as determined by the particular test conducted on the collected sample (Lbs/Day = MGD x mg/l x 8.34). The periodic (monthly or quarterly) average for the sample measurement column should be determined by dividing the sum of the individual values of "Lbs/Day" computed for each sample by the number of samples in the period. Weekly averages should be computed the same way for each week during the period in which a sample or samples were collected and tested. The maximum weekly average thus determined should be reported in the designated space.

5. Quality or Concentration - When applicable, this triple-column information is usually expressed in units such as "milligrams/liter" (mg/l), "standard units" (SU), "number/100 milliliters", or percent (%), depending on the parameter being monitored. As was the case with the Quantity or Loading columns, the horizontal spaces entitled "Permit Requirement" should contain those values (minimum, average, or maximum) allowed by the NPDES permit. Such information is usually printed on the forms provided by the Office of Pollution Control. The horizontal spaces for "Sample Measurement" should show minimum, average, or maximum values as called for by the permit based upon results of testing conducted on the collected samples. The "minimum" column should, when called for, contain the lowest test result obtained for each parameter during the monitoring period. The "average" column should contain the periodic average (monthly or quarterly) of the test results. Averages should be determined by dividing the sum of the test results by the number of tests conducted. The "maximum" column should contain either the highest test result during the monitoring period or the highest weekly average as indicated by the permit requirement.

6. No. Ex. - The total number of measurements for each parameter which exceeded <u>either</u> the maximum or minimum permissible limit during the monitoring period should be shown in the upper space designated for "Sample Measurement". The lower space designated for "Permit Requirement" should contain no information.

7. Frequency of Analysis - In the lower space designated for "Permit Requirement", the number of samples required by the NPDES permit for each parameter should be shown. This information will usually be printed on the forms furnished by the Office of Pollution Control. In the upper space designated for "Sample Measurement", the frequency of samples actually taken and analyzed during the monitoring period for each parameter should be shown. This can be done either by reporting the total number of samples taken during the monitoring period (for example, "12/30" would mean 12 samples were taken in a 30-day period); or by reporting the number of samples taken on a weekly basis (for example, "1/7" would mean that 1 sample was taken every 7 days). In either case, the actual number of samples taken and analyzed should be reported even if said number is more or less than that printed on the form or required by the permit.

Exhibit 12-6
Monthly Performance Report for Activated Sluge Systems

Month ________________ 19 ______ City of Clearwater, Mississippi Wastewater Treatment Facility Operator ____________

Date		Weather • __ A.M.		Influent						Aeration							Return Sludge			Aerobic Digestion					Effluent							Flow
DAY OF THE WEEK	DAY OF MONTH	RAINFALL (M)	TEMP (°F)	TEMP. (°C)	PH	BOD, (mg/l)	NH_3, (mg/l)	TSS (mg/l)	VSS (mg/l)	D.O. (mg/l)	MLSS (mg/l)ML VSS	(mg/l)	30-Minute Setteability (mg/l)	SV1	SLUDGE AGE (DAYS)	F/M RATIO	RETURN RATE (MGD)	% SOLIDS	% VOLATILE	GALLONS TO DIGESTER	GALLONS TO BEDS	D.O. (mg/l)	MIXED LIQUOR % SOLID	MIXED LIQUOR % VOLATILE	pH	D. O. (mg/l)	BOD, (mg/l)	NH_3, (mg/l)	TSS (mg/l)	Fecal colform (Col./100ml)	CHLORINE RESIDUAL (mg/l)	AVG. DAILY FLOW (MGO
MAX																																
MIN.																																
AVG																																

Exhibit 12-7
Monthly Performance Report for Trickling Filter Systems

Month __________ 19 ____   City of Clearwater, Mississippi   Operator ____________________
Wastewater Treatment Facility

Date		Weather • __ A.M		Influent						Primary Effluent			Plant Effluent							Flow	
DAY OF THE WEEK	DAY OF MONTH	RAINFALL (M)	TEMP (°F)	TEMP. (°C)	pH	BOD, (mg/l)	TSS (mg/l)	VSS (mg/l)	NH_3, (mg/l)	pH	BOD, (mg/l)	TSS (mg/l)	pH	D.O. (mg/l)	BOD, (mg/l)	TSS (mg/l)	NH_3, (mg/l)	Fecal coliform (Col./100ml)	CHLORINE RESIDUAL (mg/l)	AVG. DAILY FLOW (MGO)	RECIRCULATION RATE (MGD)
MAX																					
MIN.																					
AVG																					

Exhibit 12-8
Monthly Performance Report for Lagoon Systems

Month ___________ 19 _____ | City of Clearwater, Mississippi Wastewater Treatment Facility | Operator ____________________

Date		Weather • __ a.m.		Influent					Plant Effluent								Flow
DAY OF THE WEEK	DAY OF MONTH	RAINFALL (M)	TEMP (°F)	TEMP. (°C)	pH	BOD, (mg/l)	TSS (mg/l)	NH_3, (mg/l)	pH	D.O. (mg/l)	BOD, (mg/l)	TSS (mg/l)	NH_3, (mg/l)	Fecal Coliform (Col./100ml)	CHLORINE RESIDUAL (mg/l)	COLOR	INSTANTANEOUS FLOW MGD)
MAX																	
MIN.																	
AVG																	

Exhibit 12-9
Monthly Performance Report for Anaerobic Digesters

Month ____________ 19 _____ City of Clearwater, Mississippi Operator ______________________

Wastewater Treatment Facility

Date		Raw Sludge					Digested Sludge								Gas	Sludge Disposal						Supernatant			
Day of the Week	Day of Month	Gallons/Day	% Solids	% Volatile	pH	Scum (GPD)	Temp (°F)	% Solids	% Volatile	Volatile Solids Reduction (%)	pH	Volatile Acids (mg/l)	Alkalinty (mg/l)	Volatile Acids/ Alkalinty Ration	Production (CF/Day)	Gallons to Bed	Bed No	% Solids	% Volatile	Dry Solids (LBS)	Cake Removed (CU. YDS.)	Gallons	BOD, (mg/l)	TSS (mg/l)	VSS (mg/l)
MAX																									
MIN.																									
AVG																									

PERMITTEE NAME/ADDRESS *(Include Facility Name/Location if Different)*
NAME Town of Clearwater
ADDRESS P. O. Box 57
Clearwater, MS 38756

FACILITY Clearwater WWTF
LOCATION Clearwater, MS

NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM *(NPDES)*
DISCHARGE MONITORING REPORT *(DMR)*

MS0026286	001
PERMIT NUMBER	DISCHARGE NUMBER

	MONITORING PERIOD						
	YEAR	MO	DAY		YEAR	MO	DAY
FROM	93	05	01	TO	93	05	31

Form Approved.
OMB No. 2040-0004

EXHITIT 12-10
"EXAMPLE" NPDES REPORT

NOTE: Read Instructions before completing this form.

PARAMETER		QUANTITY OR LOADING: AVERAGE	QUANTITY OR LOADING: MAXIMUM	QUANTITY OR LOADING: UNITS	QUANTITY OR CONCENTRATION: MINIMUM	QUANTITY OR CONCENTRATION: AVERAGE	QUANTITY OR CONCENTRATION: MAXIMUM	QUANTITY OR CONCENTRATION: UNITS	NO. EX	FREQUENCY OF ANALYSIS	SAMPLE TYPE
BOD, 5-DAY (20 DEG. C) 00310 G 0 0 RAW SEW/INFLUENT	SAMPLE MEASUREMENT	879	1,327		* * * * *	153	259		0	4/31	Comp 24
	PERMIT REQUIREMENT	Report MO AVG	Report MX WK AV	LBS/DAY	* * * * *	Report MO AVG	Report MX WK AV	MG/L		Once/ Month	Comp 24
BOD, 5-DAY (20 DEG. C) 00310 1 0 0 EFFLUENT GROSS VALUE	SAMPLE MEASUREMENT	17	23		* * * * *	3	4		0	4/31	Comp 24
	PERMIT REQUIREMENT	100 MO AVG	150 MX WK AV	LBS/DAY	* * * * *	10 MO AVG	15 MX WK AV	MG/L		Once/ Month	Comp 24
pH 00400 1 0 0 EFFLUENT GROSS VALUE	SAMPLE MEASUREMENT	* * * * *	* * * * *		6.5	* * * * *	8.2		0	18/31	Grab
	PERMIT REQUIREMENT	* * * * *	* * * * *	* * * * *	6.0 Minimum	* * * * *	8.5 Maximun	SU		Once/ Month	Grab
SOLIDS, TOTAL SUSPENDED 00530 1 0 0 RAW SEW/INFLUENT	SAMPLE MEASUREMENT	664	773		* * * * *	113	146		0	4/31	Comp 24
	PERMIT REQUIREMENT	Report MO AVG	Report MX WK AV	LBS/DAY	* * * * *	Report MO AVG	Report MX WK AV	MG/L		Once/ Month	Comp 24
SOLIDS, TOTAL SUSPENDED 00530 1 0 0 EFFLUENT GROSS VALUE	SAMPLE MEASUREMENT	22	27		* * * * *	4	5		0	4/31	Comp 24
	PERMIT REQUIREMENT	300 MO AVG	450 MX WK AV	LBS/DAY	* * * * *	30 MO AVG	45 MX WK AV	MG/L		Once/ Month	Comp 24
FLOW IN CONDUIT OR THRU TREATMENT PLANT 50050 1 0 0 EFFLUENT GROSS VALUE	SAMPLE MEASUREMENT	0.90	* * * * *		* * * * *	* * * * *	* * * * *		0	7/7	Cont.
	PERMIT REQUIREMENT	1.2 MO AVG	* * * * *	MGD	* * * * *	* * * * *	* * * * *	* * * * *		Three/ Week	Inst.
CHLORINE, TOTAL RESIDUAL 50060 1 0 0 EFFLUENT GROSS VALUE	SAMPLE MEASUREMENT	* * * * *	* * * * *		* * * * *	* * * * *	0		0	3/7	Grab
	PERMIT REQUIREMENT	* * * * *	* * * * *	* * * * *	* * * * *	* * * * *	0.013 MO MAX	MG/L		Three/ Week	Grab

NAME/TITLE PRINCIPAL EXECUTIVE OFFICER			TELEPHONE		DATE		
John Q. Official Mayor	I Certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is , to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.		601	961-5171			
TYPED OR PRINTED		SIGNATURE OF PRINCIPAL EXECUTIVE OFFICER OR AUTHORIZED AGENT	AREA CODE	NUMBER	YEAR	MO	DAY

COMMENTS AND EXPLANATION OF ANY VIOLATIONS *(Reference all attachments here)*

EPA Form 3320-1 (REV 3/99) Previous editions may be used. THIS IS A 4-PART FORM PAGE 1 OF 2

EXHIBIT 12-10

NPDES REPORT

PERMITTEE NAME/ADDRESS *(Include Facility Name/Location if Different)*
NAME Town of Clearwater
ADDRESS P. O. Box 57
Clearwater, MS 38756

FACILITY Clearwater WWTF
LOCATION Clearwater, MS

NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM *(NPDES)*
DISCHARGE MONITORING REPORT *(DMR)*

PERMIT NUMBER	DISCHARGE NUMBER
MS0026286	001

MONITORING PERIOD

	YEAR	MO	DAY		YEAR	MO	DAY
FROM	93	05	01	TO	93	05	31

Form Approved.
OMB No. 2040-0004

EXHIBIT 12-10
"EXAMPLE" NPDES REPORT
(Continued)

NOTE: Read Instructions before completing this form.

PARAMETER		QUANTITY OR LOADING AVERAGE	QUANTITY OR LOADING MAXIMUM	QUANTITY OR LOADING UNITS	QUANTITY OR CONCENTRATION MINIMUM	QUANTITY OR CONCENTRATION AVERAGE	QUANTITY OR CONCENTRATION MAXIMUM	QUANTITY OR CONCENTRATION UNITS	NO. EX	FREQUENCY OF ANALYSIS	SAMPLE TYPE
NITROGEN, AMMONIA TOTAL (ASN) 00610 G 0 0 RAW SEW/INFLUENT	SAMPLE MEASUREMENT	97	100		* * * * *	16.3	21.0		0	4/31	Comp 24
	PERMIT REQUIREMENT	Report MO AVG	Report MX WK AV	LBS/DAY	* * * * *	Report MO AVG	Report MX WK AV	MG/L		Once/Month	Comp 24
NTIROGEN, AMMONIA TOTAL (ASN) 00610 G 0 0 EFFLUENT GROSS VALUE	SAMPLE MEASUREMENT	0.26	0.37		* * * * *	0.04	0.06		0	4/31	Comp 24
	PERMIT REQUIREMENT	40 MO AVG	60 MX WK AV	LBS/DAY	* * * * *	4 MO AVG	6 MX WK AV	MG/L		Once/Month	Comp 24
OXYGEN, DISSOLVED 00300 1 0 0 EFFLUENT GROSS VALUE	SAMPLE MEASUREMENT	* * * * *	* * * * *		7.4	* * * * *	* * * * *		0	16/31	Grab
	PERMIT REQUIREMENT	* * * * *	* * * * *	* * * * *	6.0 MO MIN	* * * * *	* * * * *	MG/L		Once/Month	Grab
BOD, 5-DAY PERCENT REMOVAL 81010 K 0 0 PERCENT REMOVAL	SAMPLE MEASUREMENT	* * * * *	* * * * *		98	* * * * *	* * * * *		0	1/31	CALTD
	PERMIT REQUIREMENT	* * * * *	* * * * *	* * * * *	85 MO AVG	* * * * *	* * * * *	Per-Cent		Once/Month	CALCTD
SOLIDS, SUSPENDED PERCENT REMOVAL 81011 K 0 0 PERCENT REMOVAL	SAMPLE MEASUREMENT	* * * * *	* * * * *		97	* * * * *	* * * * *		0	1/31	CALTD
	PERMIT REQUIREMENT	* * * * *	* * * * *	* * * * *	85 MO AVG	* * * * *	* * * * *	Per-Cent		Once/Month	CALCTD
	SAMPLE MEASUREMENT										
	PERMIT REQUIREMENT										
	SAMPLE MEASUREMENT										
	PERMIT REQUIREMENT										

NAME/TITLE PRINCIPAL EXECUTIVE OFFICER
John Q. Official
Mayor
TYPED OR PRINTED

I Certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is , to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

SIGNATURE OF PRINCIPAL EXECUTIVE OFFICER OR AUTHORIZED AGENT

TELEPHONE AREA CODE	NUMBER	DATE YEAR	MO	DAY
601	961-5171			

COMMENTS AND EXPLANATION OF ANY VIOLATIONS *(Reference all attachments here)*

EPA Form 3320-1 (REV 3/99) Previous editions may be used. THIS IS A 4-PART FORM PAGE 2 OF 2

EXHIBIT 12-10

NPDES REPORT

8. Sample Type - The lower space designated for “Permit Requirement” should contain the type sample required for each parameter by the NPDES permit. This information is usually printed on the forms furnished by the Office of Pollution Control. The upper space designated for “Sample Measurement” should contain the type sample actually collected for each parameter. Examples of sample types which might be reported for various parameters include:

   a. Continuous/Recorded - Reported when measurement of the parameter is achieved by means of an automatic analyzer on a 24-hour, 7-day per week basis with results continuously recorded on a chart; can be abbreviated as “Cont” in the allotted space;

   b. 24-hour Composite - Reported when a sample is collected and composited over a 24-hour period, preferably by means of an automatic sampler; also acceptable is a sample comprised of grab samples collected at least every 4 hours and composited over 24 hours; can be abbreviated as “Comp24” in the allotted space;

   c. 8-hour Composite - Reported when a sample is collected and composited over an 8-hour period, preferably by means of an automatic sampler; also acceptable is a sample comprised of grab samples collected every 2 hours and composited over an 8-hour period; can be abbreviated as “Comp8” in the allotted space;

   d. Grab - Reported when a single sample is collected at a particular time and place; can be shown as “Grab” in the allotted space;

   e. Instantaneous - Reported when an analysis is obtained immediately at the site; can be abbreviated as “Instan” in the allotted space; and

   f. Calculated - Utilized when the reported result is obtained by mathematical calculation (example is percent removal); can be abbreviated as “Calctd” in the allotted space.

As standard practice, all blanks on the discharge monitoring report should be filled in for each parameter unless there is no discharge during the reporting period. Reports should be <u>signed and dated</u> by a responsible representative of the permit holder. Private laboratories retained to conduct the sampling and/or analyses should <u>not</u> sign the report.

12-4 <u>MAINTENANCE RECORDS</u>

a. <u>General</u>

It has become virtually impossible for an owner of a wastewater treatment facility to comply with today’s pollution control requirements without practicing effective maintenance. A major part of practicing proper maintenance is keeping accurate records. Maintenance records should include such items as an equipment record system, work schedules, inventory systems, and budget/maintenance costs.

b. <u>Equipment Records</u>

An equipment record system should contain pertinent information on each item of equipment. Such a system will provide information on frequency of preventive maintenance, corrective maintenance performed, and costs of maintenance and repairs. Each item of equipment should be assigned an identification number and an equipment card identified by the same number. On each card should be recorded such information as:

1. Name and location of equipment,
2. Name, address, and telephone number of manufacturer and nearest representative,
3. Installation date,
4. Type, model, etc.,
5. Capacity, size, rating, etc.,

6. Serial number,
7. Initial cost,
8. Nature and frequency of recommended maintenance, and
9. Recommended lubricants and coatings.

The back of the card can be used to keep up with such information as date of any maintenance, the type maintenance, and the name or initials of the person who performed the work. Exhibit 12-11 shows an example equipment record card. In larger facilities, it is suggested that "work order" forms be utilized to keep records of all work performed.

c. Maintenance Schedules

A sanitary sewerage system and wastewater treatment facility usually consist of several operations and processes, each performing a specific task that contributes to the overall service provided. Any interruption in the operation of the individual operations and processes could result in improper sewer service, a deterioration in effluent quality at a treatment plant, and/or a violation of NPDES permit requirements. In addition, a sewer system and treatment facility must operate year-round regardless of weather conditions, holidays, and vacations. Consequently, in order to provide for smooth uninterrupted operation as well as utilizing the full potential of operating personnel, prior planning and scheduling of all maintenance work should be practiced.

A maintenance plan involves time, personnel, equipment, schedules, and costs. All of these items are best utilized when preventative maintenance is practiced, thereby minimizing corrective maintenance. Preventive maintenance is the work done to prevent breakdown, improve efficiency, reduce wear, and extend the life of equipment and structures. Preventive maintenance is normally carried out according to the manufacturer's recommendations.

Scheduling of preventive maintenance is an important part of any preventive maintenance program. To establish an efficient schedule, it is necessary to be familiar with servicing procedures of each item of equipment and the function each item of equipment plays in the overall performance of the sewer system and the treatment plant. The following is an outline of the basic steps required to effectively schedule preventive maintenance activities:

Step 1 - List all equipment requiring preventative maintenance. Use equipment catalog for this step.

Step 2 - Determine the preventive maintenance requirements and their respective frequencies for each item of equipment. This information should be in an equipment card file.

Step 3 - Estimate the time and skills required to perform each preventive maintenance task.

Step 4 - List all preventive maintenance tasks in the weekly frequency group.

Step 5 - Establish a preventive maintenance schedule. This schedule must be adjusted for corrective maintenance requirements; monthly, quarterly, semi-annual, and annual preventive maintenance requirements; and any other items that would take maintenance time away from weekly preventive maintenance activities.

Step 6 - On a yearly calendar select tentative dates for performing all monthly, quarterly, semi-annual and annual maintenance.

Step 7 - The schedule now becomes the basic maintenance schedule for planning each week's maintenance activities.

Step 8 - Each week the basic schedule is modified as required to handle preventive maintenance tasks other than those in the weekly frequency group. The schedule must also be adjusted for work priority changes due to jobs being carried over from the previous week.

EXHIBIT 12-11

EXAMPLE EQUIPMENT RECORD

ITEM	MODEL/SERIAL NO.	EQUIPMENT NO	MANUFACTURER	LUBRICATION DATA

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
January																															
February																															
March																															
April																															
May																															
June																															
July																															
August																															
September																															
October																															
November																															
December																															

MAINTENANCE ACTIVITY CODE

D	Daily	
W	Weekly	
M	Monthly	
Q	Quarterly	
B	Bi-Annually	
A	Annually	
R	Repair	
O	Out of Service	

EQUIPMENT REPAIR LOG

Date	Type of Repair	Down Time	Costs

EXHIBIT 12-12

STOREROOM FOR SPARE PARTS

Step 9 - Planning and scheduling preventive maintenance is a continuous function. Planning must take contingencies into account and scheduling must be flexible enough to handle maintenance emergencies.

Step 10 - Using a basic schedule for planning each week's preventive maintenance activities will help insure the maintenance effort is properly coordinated and directed.

d. Inventory System

A central storeroom for spare parts, equipment, special tools, and supplies should be established. This will insure these items are available for repairs and maintenance work required to keep a system operating efficiently and, most importantly, without interruptions which may be caused by the unavailability of spare parts or other such items. Exhibit 12-12 shows a well-maintained and properly-stocked storeroom. The quantity of such items to be kept in stock should be determined from the nature of the equipment on hand and the sources of supply. A review of the equipment manufacturer's recommendations will aid in determining what spare parts and miscellaneous supplies

EXHIBIT 12-13

SPARE PARTS INFORMATION

Item	Manufacturer's Name	Address	Telephone No.

Equipment No.	Model No.	Serial No.	Motor Nameplate Data

			Replacement Parts		
Part Description	Part No.	Vendor's Name	Vendor's Address & Telephone	Estimated Cost	Estimated Delivery

should be maintained. A record of spare parts for each piece of equipment can be maintained on a form similar to that shown in Exhibit 12-13. Failure to carry an inventory of items which are used on a routine basis is considered poor management while maintaining a supply of readily available and/or seldom used items is wasteful. The delivery time required for items such as valves, bearings, or other wearing parts, must be considered when deciding what items should be carried in an inventory. All items in storage should be properly labeled and each item's location correctly identified in a storage catalog. A card file system can be used to maintain an inventory record. Such information as quantity in storage, parts description, cost, supplier, order dates, and a minimum and maximum quantities to be maintained should be recorded.

e. Maintenance Costs/Budget

The importance of adequate maintenance budgets can not be overstated. A lack of funds resulting from an underestimated budget will not only be detrimental to a maintenance system but may result in costly repairs and interruption of the normal service.

In order to prepare a sound maintenance budget, accurate cost data on various maintenance operations must be established and recorded. The cost of each equipment or parts purchase, repair, alteration, and contract work items should be recorded. The compilation of such costs can be utilized in estimating a sufficient maintenance budget. Maintenance budgets are normally developed by using the data from past cost reports. The following is a checklist of items which should be included in a cost report for formulating a maintenance budget:

1. Preventative Maintenance - Cost data for preventive maintenance should include personnel man-hours utilized in performing preventive maintenance, supplies, lubricants, and other related costs. The man-hours and supplies used should be broken down by craft. Review of time sheets and jobs performed will provide a basis for determining the previous years' maintenance man-hours which can be used for estimating maintenance budgets for the coming year. The equipment history records should contain a detailed description of the item and register total maintenance hours and cost.

2. Corrective Maintenance - Corrective maintenance is the repairs performed while a system or facility is in operation or with a minimum of equipment downtime. These maintenance functions include packing pumps, changing belts, replacing bearings, repairing broken sewer mains, etc.

   Like preventive maintenance, cost data for corrective maintenance should be compiled. Review of the equipment history records will provide a basis for estimating repair costs associated with a specific item or equipment. The equipment history record should contain a detailed description of the item and register total maintenance hours and costs.

3. Major Repairs - Major repairs or alterations generally occur when a unit is out of service and are performed by maintenance men or are contracted out. In estimating a budget for major repairs, active backlog projects as well as current projects which have received approval should be included. To these items must be added the forecast for next year's needs which may include equipment overhauls, modifications, any alterations, and building repairs.

4. Contract Maintenance or Repairs - All costs incurred for outside contract maintenance services or repairs should be included. Such items as machine shop costs, welding, re-winding electric motors, etc. are included in this category.

12-5 PERSONNEL RECORDS

A complete personnel record should be maintained on all employees, whether full-time or part-time. In addition, the applications of potential employees should be kept on file. Examples of information which should be included in an employee's record include:

1. Educational background,
2. Experience record,
3. Training and special courses taken,
4. Salary history,
5. Certifications, awards, or commendations received,
6. Record of supervisor's evaluations,
7. General health record, and
8. Letters of reference.

Certifications, awards, and commendations received by employees can be displayed such as shown in Exhibit 12-14. It is suggested that employees be evaluated on an individual basis with regard to job performance, and that the results of the evaluation be duly recorded by authorized persons in the employee's file.

12-6 BUDGET & OPERATING COSTS

An itemized record of the operating budget and all purchases and expenses should be kept. Costs should be broken down into budgeted categories as needed. Typical categories include:

1. Salaries and wages,
2. Electricity,
3. Chemicals,
4. Maintenance, and
5. Staff Training.

Each expense associated with the operation and maintenance of a sewer system and treatment plant should be assigned to a budget category and recorded in a hard-bound ledger or other permanent record.

EXHIBIT 12-14

DISPLAY OF PERSONNEL CERTIFICATIONS AND AWARDS

CHAPTER 13

SAFETY

* * * * *

TABLE OF CONTENTS

CHAPTER 13

SAFETY

13-1 GENERAL

The accident frequency rate among workers in the field of wastewater collection and treatment is second only to that of the mining industry. Accidents are virtually always caused by some unsafe act or condition or combination of both. Each accident must be considered as evidence that something is wrong with procedure, design, equipment, or personnel.

Behind every accident there is usually a specific chain of events which led to an unsafe act or condition. For this reason, accidents can be prevented by using good common sense, by applying a few basic rules, and by becoming knowledgeable of the hazards which are likely to exist. Whenever a potential hazard is recognized, it should be eliminated immediately. If immediate elimination is not possible, protection should be provided by using appropriate warning devices and special precautionary procedures.

Every employer has the responsibility of providing its employees with a safe place to work. This responsibility includes providing proper tools, equipment, and materials as well as properly training and placing persons for the work to be done. Individual employees have a responsibility to themselves, their families, and their job to do everything they can to prevent accidents. This means following all safety rules and maintaining all tools, equipment, materials, and surroundings in a safe condition.

Employers should promote a safety and accident prevention program for their employees. The requirements of such a program should include the following:

1. Safety inspections of facilities and equipment should be conducted on a regular basis.
2. Safety training and education should be provided for all personnel.
3. Incentives should be provided for personnel that practice safety measures on the job.
4. The ability, aptitude, and experience of each employee should be thoroughly evaluated to be certain that an individual has the necessary qualities to handle a particular job.
5. All accidents should be investigated and a written report filed which describes the cause of the accident, the extent of injury, corrective measures taken to prevent another occurrence, and other pertinent details. An example "Accident Report Form" is shown in Exhibit 13-1.
6. Emergency telephone numbers should be posted in obvious places. The numbers of the nearest hospital, ambulance service, fire department, police or sheriff's department, etc. should be shown.
7. An illustrated poster for resuscitation procedures and first aid directions for common physical injuries should be posted in obvious and accessible locations.

Even with a well-rounded and strictly enforced safety program, the basic responsibility for doing a job safely remains with the individual worker. His or her attitude and approach toward safety will determine how effective accident prevention will be. It is up to each individual to "think safety" and "practice safety."

Persons who work in and around sanitary sewer systems and wastewater treatment facilities are exposed to various types of hazards which include the following:

DATE: ______________________________

INSURED
PERSON ____ ____
(Name) (Job Title)

DATE OF INJURY ____________________________ ____________________________ ____________ AM PM
(Day) (Month) (Time)

PLACE ACCIDENT OCCURRED ____

DESCRIPTION OF ACCIDENT ____

____

____

____

____

CORRECTIVE ACTION TAKEN ____

____

____

____

____

INSURANCE COMPANY ____

TIME LOST

DESCRIPTION OF INJURY ____________________________________

DATE	HOURS	

PERSON MAKING REPORT ____
(Name)

REMARKS,DIAGRAM, RECOMMENDATIONS, ETC.:

EXHIBIT 13-1

SAMPLE ACCIDENT REPORT FORM

1. Physical Injuries,
2. Infection and Infectious Diseases,
3. Oxygen Deficiency and Noxious Gases,
4. Fire and Explosions,
5. Chlorine Hazards,
6. Electrical Shock,
7. Laboratory Hazards, and
8. Excavations.

It is very important that both employers and employees become familiar with the common causes of these hazards and the safety practices which can prevent accidents. Exhibit 13-2 shows examples of some safety hazards commonly found at wastewater treatment facilities.

13-2 SAFETY PRACTICES

a. Physical Hazards

Unfortunately, physical injuries such as cuts, bruises, scrapes, and broken bones are common occurrences among persons who work in the field of wastewater collection and treatment. Several things can be done to prevent or at least minimize physical injuries such as including safety features in the design of facilities and providing good safety equipment for workers. However, the most important preventive is to apply common sense and put "safety first" in all work procedures. Common sense includes making certain that there is enough help on hand for the job to be done.

In sanitary sewer systems, most accidents occur when working in and around manholes, There are certain basic safety rules which should be practiced by workers to prevent physical injury. These include:

1. When removing manhole covers, lifting should be done with the legs instead of the back using proper tools. Hands should never be placed under the covers when removing or replacing.
2. Rubberized cloth gloves should be worn when opening manholes, descending and ascending manholes, and handling sewer rods and related equipment.
3. Manhole steps should be kept in good repair and inspected prior to descending a manhole. If there is any doubt as to the soundness of the steps, a ladder should be used.
4. The covers of opened manholes should be placed flat on the ground at least two feet from the manhole.
5. A manhole should never be descended without checking for noxious or explosive gases or fumes. A positive displacement blower should be used for removing gases and fumes.
6. A safety harness should be worn when descending a manhole and at least two men should be available for lifting a worker from the manhole in the event of injury.
7. Illumination in manholes should be provided by using explosion-proof lamps.

Sewer cleaning, maintenance, and repair should be done under the supervision of a foreman who is trained in first-aid and who has proper first-aid equipment readily available on the job. Where a work zone is needed in a traffic area, workers and traffic should be protected by adequate signs, barriers, or police protection.

MISSING GRATE AND HOSE ON WALKWAY

TOOLS ON WALKWAY AND IMPROPERLY STORED MATERIALS

IMPROPERLY STORED CHLORINE CONTAINER

MISSING HANDRAIL ON EFFLUENT STRUCTURE

EXHIBIT 13-2

COMMON SAFETY HAZARDS AT WASTEWATER FACILITIES

Just as in a sewer system, prevention of physical injury at wastewater treatment facilities and pumping stations usually can be achieved by practicing common sense safety measures. Good housekeeping and maintenance practices will go a long way toward reducing hazards and preventing accidents. General safety practices which should be followed at treatment facilities and pumping stations include the following:

1. All structure and appurtenances should be kept in good repair and maintained in a neat condition.
2. Tools, materials, and equipment should not be left laying around. Good housekeeping should be practiced at all times. Everything should be placed in its proper place when not in use.
3. Walkways should be kept free of grease, oil, ice, and any debris, tools, materials, or equipment which might cause someone to trip or slip.
4. Handrails and grating should always be kept in good rust-free condition.
5. When descending a drained tank, a ladder should be used. The ladder should be tied at the top.
6. Water hoses should never be left draped across gratings, handrails, or walkways.
7. When descending manholes, wet wells, or other underground structures, a safety harness should be worn and at least two men should be at the surface while a worker is in these structures.
8. When working around tank units, a worker should always be alert for possible slippage. Flotation devices and safety ropes should be strategically placed around tank units.
9. A tank should never be entered unless additional personnel are in the immediate vicinity to help in case of a fall.
10. When removing or installing equipment, a worker should be aware of the limitations of the working area.
11. Special care should be taken to prevent working on electrical equipment or wiring with wet hands, clothes, or shoes.
12. All equipment with moving parts such as belts, chains, and gears should have guards or shields around such parts.
13. A worker should never wear loose clothing or jewelry when working around equipment with exposed moving parts.
14. Electrically-powered equipment should never be serviced or repaired unless the power supply is off, locked, and tagged.
15. A wet well, manhole, or similar structure should never be entered without checking for noxious and explosive gases. If required, the structure should be ventilated by a positive displacement blower.
16. No smoking or open flames should be allowed in or near wet wells, manholes, digester tanks, etc. Only explosion proof lights and tools should be used when working in such areas.
17. A worker should never attempt to carry tools or equipment up or down ladders. Instead, a bucket and handline should be used.

b. Infection and Infectious Diseases

Domestic wastewater contains pathogenic as well as non-pathogenic organisms. Pathogenic organisms are disease-causing bacteria. Many water borne diseases (typhoid fever, paratyphoid fever, cholera, amoebic dysentery, etc.) can be caused from waters being contaminated with municipal wastewaters. In recent years, the number of cases of bacterial infections at wastewater treatment plants has decreased to a minimum. This may be attributed to such factors as advances in treatment plant design providing safer working conditions and greater freedom from direct contact with wastes and their by-products; better medical care and the use of antibiotics; and better trained and educated operating personnel.

However, with the remarkable reduction in the number of infections, the importance of preventing them can hardly be overemphasized. The best defense against infection is the practice of good personal hygiene and prompt medical attention for any injury that breaks the skin. The following practices will minimize the risk of infection and infectious disease:

1. Immunization shots against typhoid and tetanus should be mandatory.
2. Each worker should make it a habit to thoroughly wash hands with a disinfectant soap before eating, drinking, smoking or going to the lavatory. Lysol at a concentration of 1¼ oz. per gallon of water can be used.
3. If practicable, workers should not wear work clothes home because diseases may be transmitted to family members. It is desirable that workers change into work clothes for working hours.
4. All work clothes should be laundered separately from regular family wash.
5. For all but very minor injuries, a doctor should be consulted.
6. Rubber gloves should be worn to prevent infection while cleaning pumps, handling wastewater screenings, sludge, grit, or other infectious materials.
7. Each worker should be familiar with first-aid procedures. Such procedures are available from state health departments, the National Safety Council, the Federal Bureau of Mines, and the American Red Cross. Emergency first-aid kits should be available for treating minor cuts, burns and wounds. A tincture of merthiolate is recommended for immediate use on minor cuts and wounds.

One of the most widely-discussed and dreaded diseases imposed on society today is acquired immune deficiency syndrome (AIDS) which is caused by the human immunodeficiency virus (HIV). Many questions have been raised by persons who work in the wastewater field regarding the possible transmission of AIDS from human wastes such as urine, fecal matter, blood, and other body fluids that are discharged to sewer systems and wastewater treatment facilities. HIV is a blood-borne virus and cannot reproduce outside the human body. To be transmitted, the virus must enter the bloodstream directly.

While it is possible for a blood-borne virus from wastewater to enter the human body through an open wound or skin abrasion, merely coming in contact with contaminated wastewater does not mean that one has been exposed to AIDS or any other disease. Any AIDS virus which might be contained in a wastewater discharge is subjected to large dilutionary effects and the harsh environment of a sewer system (low levels of heat, pH variations and extremes, chemical agents, surfactants, etc.). Because the AIDS virus is delicate and cannot survive for long periods of time outside the human body, such conditions are not conducive to its survival.

According to the Centers for Disease Control (CDC), there is no scientific evidence that HIV is spread in wastewater. Further, there are no known cases of wastewater workers having contracted AIDS via occupational exposure. The Water Pollution Control Federation (now the Water Environment Federation) in its 1991 publication entitled "Biological Hazards at Wastewater Treatment Facilities" states that "the scientific evidence to date indicates that AIDS cannot be contracted through occupational exposure associated with wastewater treatment." The same publication also states that the AIDS virus "is not well suited to the collection system environment and is likely to become deactivated upon contact with wastewater." All information compiled to date on the matter suggests that on-the-job risks of contracting AIDS are virtually non-existent for wastewater workers. Nevertheless, workers should always do what they can to minimize exposure to disease by practicing good personal hygiene and by exercising caution and common sense on the job.

c. Oxygen Deficiency and Noxious Gases

Oxygen deficiency may exist in any enclosed, and particularly below grade, un-ventilated structures where a gas heavier than air, such as carbon monoxide, has displaced the air. Noxious gases are gases that are directly or indirectly injurious or destructive to the health or life of human beings. They may cause burns, explosions, asphyxiation, or poisoning. Non-poisonous gases may asphyxiate simply by mechanically excluding oxygen.

The places which are most likely to be dangerous from a noxious gas or vapor situation or oxygen deficiency are deep tanks, manholes, and wet wells. The composition of such gases is usually a combination of carbon dioxide, hydrogen sulfide, and methane in proportion depending on the origin of the gas.

The following are general safety practices which should be followed to minimize hazards and adverse effects of oxygen deficiency or noxious gases:

1. Oxygen deficiency detectors should be used before entering any potential hazardous area.
2. Air should be forced into any suspected area before entering. A positive displacement blower is recommended and should be left in service as long as a worker is in the area.
3. The necessary safety equipment should be kept on hand and workers should become familiar with all safety precautions.
4. No worker should enter a suspected area alone. One or more co-workers should be available in case help is needed.

The use of detection equipment can prevent serious injury and death. The various types of detection equipment are presented hereinafter in Section 13-3.

d. Fire and Explosions

Fire may occur wherever gas may leak, and explosions whenever an explosive mixture receives the ignition necessary to set if off. Such ignition may come from a lighted cigarette, a broken light bulb in an ordinary extension cord and fixture, a sparking switch, sparks from shoe nails or tools, and the use of ordinary flash lights. Consequently, extreme care should be followed in working in or around areas where such gases are produced.

Good safety practices with respect to fire and explosion prevention require a knowledge of the following:

1. Ingredients necessary for a fire - The three (3) essential ingredients of all ordinary fires are fuel, heat, and oxygen. Paper, wood, oil, solvents, and gas are common fuels. Enough heat must be provided to vaporize the fuel according to its nature. Normally, at least 15% of oxygen in the air is necessary to sustain a fire.
2. Fire control methods - To extinguish a fire, it is necessary to remove only one of the aforementioned essential ingredients. Fires burning from such combustibles as wood, cloth, paper or rubbish are usually extinguished by cooling with water. Fires burning from flammable liquids such as gasoline, oil, grease, or paint are usually smothered by using foam, carbon dioxide, or a dry chemical. Fires resulting from electrical equipment are usually smothered by the use of carbon dioxide or dry-chemical extinguishers. The operator should know exactly where fire extinguishers are kept and where water hydrants are located.
3. Fire prevention practices - Fires can be prevented by:
    a. Maintaining a neat and clean work area, preventing accumulation of rubbish.

b. Putting oil and paint soaked rags in covered metal containers.

c. Observing all “no smoking” signs.

d. Keeping fire doors, exits, stairs, and catwalks clean of obstructions.

e. Keeping all burnable materials away from any source of ignition.

f. Reporting any fire hazards that are beyond control, especially electrical hazards.

g. Knowing how and when to use a fire extinguisher.

e. Chlorine Hazards

The most common causes of accidents involving chlorine gas are leaking pipe connections and over-chlorinating. Chlorine leaks are very dangerous since the gas is an irritant to the nose, throat, and lungs and causes violent coughing and, in large concentrations, will cause death. Chlorine odor is detectable at a concentration of 3.5 mg/l in air; 4 mg/l is the maximum concentration that can be breathed for one hour without harmful effects; 15 mg/l causes throat irritation; 30 mg/l causes coughing; 40 mg/l to 60 mg/l is dangerous when inhaled for 30 minutes or more; and 1000 mg/l may cause death after 5 minutes exposure.

Chlorine is a gas, heavier than air, extremely toxic and corrosive in moist atmosphere. Dry chlorine gas can be safely handled in steel containers and piping, but with moisture it must be handled in corrosion-resistant materials such as silver, glass, teflon, and certain other plastics. Chlorine gas at container pressure should never be piped in silver, glass, teflon, or any plastic material.

Because the characteristic sharp odor of chlorine is noticeable even when the amount in the air is small, it is usually possible to get out of the gas area before serious harm is suffered. This feature makes chlorine less hazardous than gases such as carbon monoxide, which is odorless, and hydrogen sulfide, which impairs your sense of smell in a short time.

Inhaling chlorine causes general restlessness, panic, severe irritation of the throat, sneezing, and production of much saliva. These symptoms are followed by coughing, vomiting, and difficulty in breathing. Chlorine is particularly irritating to persons suffering from asthma and certain types of chronic bronchitis. Liquid chlorine causes severe irritation and blistering on contact with the skin.

Every person working with chlorine should know the proper ways to handle it; should be trained in the use of gas masks or breathing apparatus; and should know what to do in case of an accident or emergency. Some of the items which should be remembered for protection against injury are:

1. In an emergency, only authorized persons with adequate safety equipment should be in the danger area.
2. In any chlorine atmosphere, short shallow breathing is safer than deep breathing. Recovery from exposure depends on the amount of chlorine inhaled, so it is important to keep that amount as small as possible.
3. Clothing contaminated with liquid or gaseous chlorine continues to give off chlorine gas and irritate the body even after leaving a contaminated area. Therefore, contaminated clothing should be removed immediately and the exposed parts of the body washed with a large amount of cool water. The use of a breathing apparatus is advisable during these operations. All caution should be taken to prevent any liquid from coming in contact with clothing not designed for protection, because the liquid can penetrate the cloth and cause skin problems.

4. Each worker should learn the correct way of using the gas mask or breathing apparatus, practice using it regularly, and take safety drills seriously.
5. When repairing chlorine leaks, a worker should not rely on canister gas masks for protection. Canister masks do not supply oxygen. They only remove chlorine, if effective. An oxygen supplying breathing apparatus should be obtained for repairing any major leak. Extensive ventilation also is recommended before, during, and after repair.
6. Workers should cooperate in taking care of all safety equipment, handling it carefully, and returning it to its proper storage place after use.
7. Workers should always be sure of the location of first-aid cabinets, breathing apparatus, showers, and other safety equipment. Emergency instructions should be reviewed regularly.
8. The police or sheriff's department should be notified for help if it becomes necessary to stop traffic on roads and to evacuate persons in the vicinity of a chlorine leak.
9. Even the slightest leak should be corrected immediately upon detection.
10. A chlorinator or cylinder storage room should always be entered with caution. If chlorine is detected when opening the door, the door should be closed immediately, ventilation turned on, and assistance sought.
11. A worker should never attempt to enter an atmosphere of chlorine alone or without a proper gas mask or breathing apparatus and protective clothing.
12. Since chlorine gas is approximately 2½ times heavier than air, vents or an exhaust fan should be provided in good operating condition at all times in the cylinder storage area and chlorinator room. Vents and exhausts should be located at floor level.
13. Gas masks and breathing apparatus should be stored in a safe, dry, and easily accessible area outside of the cylinder storage area or chlorinator room.
14. A person should not attempt to correct a leak if he is uncertain of the proper procedures. He should seek qualified assistance from such sources as the local fire department, civil defense authorities, chlorine supplier, or chlorinator manufacturer.

Workers should be familiar with recommended first-aid measures for a chlorine accident. Knowing what to do as well as what <u>not</u> to do could prevent serious injury or damage to an individual or possibly even save his life. The recommended first-aid procedures with which workers should be familiar are as follows:

1. Be sure of the location of breathing apparatus, first-aid kits, and other safety equipment at all times.
2. Remove clothing contaminated with liquid chlorine at once. Carry patient away from gas area - if possible to a room with a temperature of 70°F. Keep him quiet.
3. Place patient with his head higher than the rest of his body.
4. <u>Call a doctor and fire department immediately.</u> Immediately begin recommended treatment.
5. <u>Eye Irritation</u> - If even small quantities of chlorine have entered the eyes, hold the eyelids apart and flush copiously with lukewarm running water. Continue flushing for about fifteen minutes. Do not attempt any medication except under specific instructions from a physician.
6. <u>Skin Irritation</u> - Get patient under a shower immediately, clothes and all. Remove clothing while the shower is running. Wash the skin with large quantities of soap and water. Do not attempt to neutralize the chlorine with chemicals. Do not apply salves or ointments except as directed by a physician.
7. <u>Inhalation</u> - If the patient is breathing, place him in a comfortable position; keep him warm and at rest until a physician arrives.

If breathing seems to have stopped, begin artificial respiration immediately; mouth-to-mouth resuscitation or any other approved methods may be used. Oxygen should be administered if equipment and trained personnel are available.

Rest is recommended after severe chlorine exposure.

8. Throat Irritation - Drinking milk will relieve the discomforts of throat irritation from chlorine exposure. Chewing gum or drinking spirits of peppermint also will help reduce throat irritation.

Cylinders containing approximately 150 pounds of chlorine gas are the most commonly utilized at wastewater facilities. These cylinders can be easily and safely handled. A fusible plug normally is placed in the cylinder valve below the valve seat. The plug is a safety device. The fusible metal softens or melts at 158˚F to 165˚F to prevent excessive pressures from building up and possibly causing rupture of the cylinder.

The following procedures should be followed for handling chlorine cylinders:

1. Move cylinders with a properly balanced hand truck and clamp supports that fasten at least two-thirds of the way up the cylinder.
2. 100- and 150-pound cylinders can be rolled into a vertical position. Lifting these cylinders should be avoided except with approved equipment. Never lift with chains, rope slings, or magnetic hoists.
3. Protective caps should always be replaced when moving cylinders.
4. Cylinders should be kept away from direct heat (steam pipes, radiators, sunlight, etc.).
5. Cylinders should be stored and secured in an upright position in a cool, dry place.

f. Electrical Shock

Extreme care should be taken in electrical work. The fact should be borne in mind that electrical energy in excess of 50 volts can be fatal providing that a good ground is made. Portable power tools should have a third wire for grounding the outside case or frame. Rubber gloves and rubber boots are advisable. If major repairs are to be made to electrical equipment, an experienced electrician should be called to do the work.

In day-to-day operation and maintenance, if a motor is to be cleaned or serviced, the safety switch should be disconnected. Workers should use the right equipment and tools and always be familiar with the work prior to starting. Listed below are good practices to follow when working with electricity.

1. A person should not ground himself in water or on pipes and drains. Avoid these materials when working with electricity.
2. Allow only authorized personnel to work on electrical equipment.
3. Always work in pairs around electrical equipment.
4. Never use metal ladders around electrical equipment.
5. When there is a question regarding any electrical hazard, a qualified person should be consulted. Never test a circuit by touching it.
6. Ground all electrical tools.
7. Always stop a motor prior to attempting any cleaning or servicing on it.
8. Keep all electrical controls accessible and well marked.
9. Keep rubber mats on the floor in front of electrical panels; keep edges trimmed so that they do not become a tripping hazard.
10. Place "Man on Line" signs and lock the switches when working on electrical equipment which another person can turn on.

11. Handle breaker wires as though they were "live" wires.
12. Provide lock-out-stop-button stations at all motors which are not within sight of the starter-circuit breaker, or which are farther than 50 feet from the starter.

Electricity is a hazard that requires careful attention. It should be treated with respect. Remember, experienced men continue to have accidents with electricity. The amateur should, therefore, take special precautions.

Electricity kills by paralyzing the nervous system and stopping muscular action. Frequently, electricity may hit the breathing center at the base of the brain and interrupt the transmission of the nervous impulses to the muscles responsible for breathing. In other cases, the electric current directly affects the heart, causing it to cease pumping blood. Death follows from lack of oxygen in the body. It is usually difficult to tell which action has taken place. For this reason, it is essential that the following steps be taken if someone experiences severe electrical shock:

1. The victim should be freed from the live conductor promptly by use of a dry stick or other nonconductor. Never use bare hands to remove a live wire.
2. CPR must by started immediately and continued until breathing is restored, until the doctor tells you to stop, or until the onset of rigor mortis.

g. Laboratory Hazards

The collection of samples and the performance of laboratory tests can involve certain hazards. All laboratory and sampling personnel should be aware of potential hazards and practice safe laboratory and sampling techniques.

All chemicals and laboratory solutions should be kept in limited amounts and used with respect. A safe and separate storage area should be designated for chemicals and solutions.

In collection of laboratory samples, the following rules should be obeyed:

1. Never collect any samples with bare hands when cuts, scratches, or other broken skin areas are present.
2. Whenever possible, rubber gloves should be worn when hands may come in direct contact with wastewater or sludge. When finishing sampling, always wash the gloves thoroughly before removing them. After removing the gloves, wash hands thoroughly, using a disinfectant type soap.
3. Do not climb over or go beyond guardrails or chains when collecting samples. Use sample poles, ropes, etc., as necessary to collect samples.

Caution should always be exercised in the laboratory during equipment set-up, mixing of reagents, or performance of tests. One overall general thing to remember is "never get in a hurry" in the lab. Failure to heed this reminder can and often results in an accident. There are several other specific safety procedures which should be followed in the laboratory to minimize the chances of an accident. These are listed below:

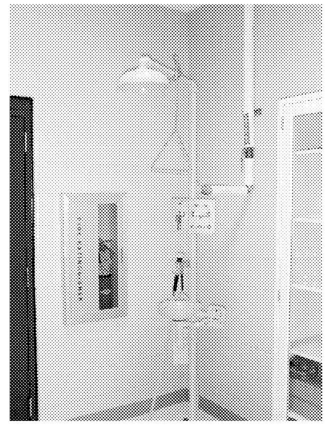
1. Never look into the open end of a container during a reaction or when heating the container.
2. Use proper safety goggles or face shield in all tests where there is danger to the eyes.
3. Use care in making rubber-to-glass connections. Lengths of glass tubing should be supported while they are being inserted into rubber. The ends of the glass should be flame polished to smooth them out, and a lubricant such as water should be used. Never use grease or oil. Gloves or some other form of protection for the hands should be used when making such connections. The tubing should be held as close to the end being inserted as possible to prevent bending or breaking. Never try to force rubber tubing or stoppers from glassware. Cut the rubber as necessary to remove it.
4. All chemical containers should be clearly labeled, indicating contents and date container was opened or solution prepared. All poisons must be labeled with a "skull and crossbones" and antidote.

5. Always check labels on bottles to make sure that the proper chemical is selected. Never permit unlabeled or undated containers to accumulate around or in the laboratory. Keep storage areas organized to facilitate chemical selection. Clean out old or excess chemicals. Separate flammable, explosive, or special hazard items for storage in an approved manner.
6. Never handle chemicals with bare hand. Use a spoon or spatula for this purpose.
7. Be sure that your laboratory is adequately ventilated. Even mild concentrations of fumes or gases can be dangerous.
8. Never use laboratory glassware for a coffee cup or food dish. This is particularly dangerous when dealing with wastewaters.
9. When handling hot equipment of any kind, always use tongs, asbestos gloves, or other suitable tools. Burns can be painful and cause more problems (encourage spills, fire, and shock).
10. When working in the lab, avoid smoking and eating.
11. Always wash hands thoroughly before eating or smoking after working in the lab.
12. Do not pipette chemicals or wastewater samples by mouth. Always use a suction bulb or an automatic burette.
13. Handle all chemicals and reagents with care. Read and become familiar with all precautions or warnings on labels. Know and have available an antidote for all poisonous chemicals kept in the lab.
14. Make certain that emergency eye wash facilities are available to flush harmful chemicals from the eyes or skin. Such facilities can range from a short section of rubber tube on a faucet to a specially purchased eye wash station.
15. Dispose of all broken or cracked glassware immediately. Chipped glassware may still be used if it is possible to fire polish the chip in order to eliminate the sharp edges. This may be done by slowly heating the chipped area until it reaches a temperature at which the glass will begin to melt. At this point remove from flame and allow to cool.
16. Never hold any piece of glassware or equipment with bare hands while heating. Always use a suitable glove or tool.
17. Wear a protective smock and apron when working in the lab. This may save the cost of replacing work clothes. Protective eye shields should be worn too.
18. Hydrochloric acid (HCl) should not be stored in close proximity to sodium hydroxide (NaOH).
19. Remember to always add acid to water, never the reverse.

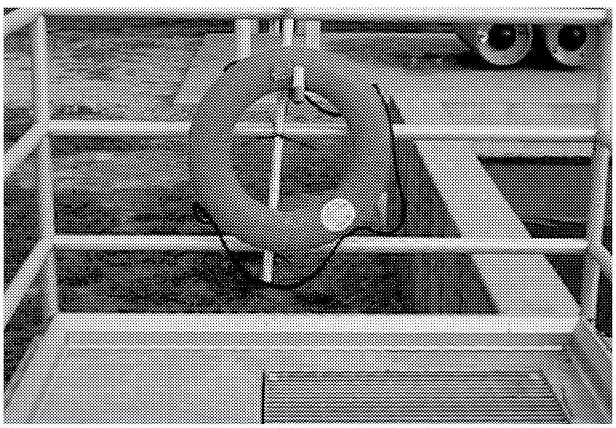
h. Excavations

Since sewers and many pumping station and treatment facility components are underground installations, the need for excavating is common when making repairs or installing new systems. Certain precautions and practices should be exercised to protect workers who have to work in and around excavations. In its regulations which govern safety and health practices in construction, the Occupational Safety and Health Administration (OSHA) sets forth specific requirements for excavation safety. Said regulations, which are contained in the Code of Federal Regulations (CFR), Title 29, Part 1926, Subpart P, require that a worker in an excavation be protected from such hazards as may exist due to surface encumbrances, existing underground utilities, unsafe access and egress, vehicular traffic, exposure to falling loads, mobile equipment, atmospheric contaminants, water accumulation, loose/unstable soil or rock, and falls. If a worker considers the conditions in which he or she is required to work to be unsafe, such concerns

ACCESSABLE SAFETY EQUIPMENT



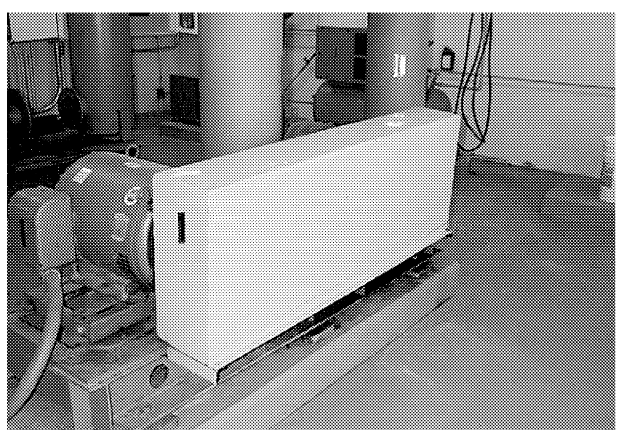
EMERGENCY SHOWER/EYEWASH



LIFE RING

NON-POTABLE WATER SOURCE WARNING

LOCKOUT DEVICE



GUARDS IN PLACE

EXHIBIT 13-3

SAFETY PRACTICES AND EQUIPMENT

should be expressed to the employer. Further concerns or questions concerning proper safety provisions can be registered with the Occupational Safety and Health Administration in Jackson, Mississippi via telephone at 965-4606.

A summary of the general requirements which should be exercised to ensure the safety of persons working in and around excavations is as follows:

1. Surface Encumbrances - All surface encumbrances that are located so as to create a hazard to workers should be removed or supported as necessary to safeguard the workers.
2. Existing Underground Utilities - The estimated location of existing underground utilities such as sewer, telephone, gas, electric, or water that may reasonably be expected to be encountered during excavation should be determined <u>before</u> digging. In the State of Mississippi, "Mississippi One Call" can be contacted toll-free via telephone at 1-800-227-6477 for assistance in location of underground utilities.
3. Access and Egress - Structural ramps used for access or egress of persons or equipment to and from excavations should be designed by a person competent in structural design and should be constructed in accordance with the design. In excavations that are four (4) feet or more in depth, a stairway, ladder, ramp or other safe means of egress should be provided which will require no more than twenty-five (25) feet of lateral travel.
4. Vehicular Traffic - Workers exposed to vehicular traffic should be provided with and should wear warning vests or other suitable garments marked with or made of reflectorized or high-visibility material.
5. Exposure to Falling Loads - Workers should not be permitted underneath loads handled by lifting or digging equipment. Workers should stand away from any vehicle being loaded or unloaded to avoid being struck by any spillage or falling materials.
6. Mobile Equipment - When mobile equipment is operated adjacent to an excavation, or when such equipment is required to approach the edge of an excavation, and the equipment operator does not have a clear and direct view of the edge of the excavation, a warning system such as barricades, hand or mechanical signals, or stop logs should be utilized.
7. Atmospheric Contaminants - Adequate precautions should be taken to prevent exposure of workers to harmful levels of atmospheric hazards like oxygen deficiencies, flammable gases, or other hazardous substances that might reasonably be expected to exist such as in excavations in landfill areas or waste disposal sites. Adequate ventilation and testing should be provided as required to safeguard workers when atmospheric contamination exists.
8. Water Accumulation - Workers should not work in excavations in which there is accumulated water or in which water is accumulating unless adequate protection is provided against the hazards posed by the water. Protection systems include, but are not limited to, special support or shield systems to protect from cave-ins, water removal to control the level of accumulating water, or use of a safety harness and lifeline.
9. Loose/Unstable Soil or Rock - Precautions should be exercised to protect workers from cave-ins in all excavations unless the excavation is made entirely in stable rock or unless the excavation is less than five (5) feet in depth and examination of the ground by a competent individual provides no indication of a potential cave-in. Protective systems should have the capacity to resist without failure all loads that are intended or could reasonably be expected to be applied or transmitted to the system. Protective systems, which include sloping and benching, timber shoring, hydraulic shoring, and trench shields, should be properly designed and constructed for each location.
10. Falls - Where workers or equipment are required or permitted to cross over excavations, walkways or bridges with guardrails should be provided. Adequate barriers should be provided at all remotely located excavations. Wells, pits, shafts, etc. should be barricaded or covered.

Details and specifications concerning OSHA requirements for excavation safety can be found in the aforementioned Code of Federal Regulations. It is recommended that all employers and employees comply fully with the requirements set forth therein.

13-3 SAFETY EQUIPMENT & SUPPLIES

In order that recommended safety practices be used by workers in sanitary sewers and wastewater treatment facilities, adequate equipment and supplies must be available. A list of basic equipment that should be provided includes the following:

a. Chlorine gas mask or oxygen supplying breathing apparatus,
b. Fire extinguisher,
c. Safety ropes and harnesses,
d. Hard hats for all personnel and visitors,
e. First-aid kits,
f. Gloves for all personnel,
g. Boots for all personnel,
h. Appropriate warning or danger signs and tags,
i. Ladders,
j. Insulated tools for servicing electrical equipment,
k. Water hoses,
l. Safety glasses,
m. Laboratory aprons,
n. Asbestos gloves or tongs for heating glassware or equipment in the laboratory,
o. Portable air blower (gas motor or electric motor operated),
p. Electric explosion-proof lantern, and
q. Chlorine emergency repair kit.

In addition to the above-cited basic equipment, certain additional equipment is recommended for prevention of fires and for detection of noxious gases. The following equipment is extremely helpful in preventing fires and explosions.

a. Combustible gas indicator,
b. Hydrogen sulfide detector,
c. Gas masks,
d. Non-sparking tools made of beryllium-copper alloy,
e. Gas-proof flashlights and extension electric lights with heavy insulated cord or other portable electric hand lamps and electric cap lamps approved by the Bureau of Mines for use in explosive atmospheres,
f. Rubber boots and rubber gloves, and
g. Portable blowers equipped with vapor-proof, totally enclosed motors or non-sparking gas engines.

The use of detection equipment can prevent serious injury or death. There are three (3) basic types of detection equipment commonly used. These are:

a. Oxygen Deficiency Indicator - This is an adaptation of the flame safety lamp used by miners. A sample of the atmosphere under test is aspirated into contact with a gauze-protected, bonneted, naphtha-burning flame unit through an intake and tube, equipped with a flashback arrester capable of preventing the propagation of hydrogen flame. An oxygen deficiency is indicated by a decreasing or extinguishing of the flame in the lamp, unless a combustible gas is also present, when a sustained increase in flame height accompanied by dimming of the flame may occur. In the presence of hazardous concentrations of flammable gas, the flame will flare up and be extinguished. Atmospheres containing less than 13 percent by volume of oxygen are considered decidedly dangerous to man. The flame of the oxygen deficiency indicator will generally be extinguished by an atmosphere containing less than 16 percent of oxygen and always by one below 13 percent of oxygen and is, therefore, a safe indicator of the suitability of an atmosphere to support life.

b. Hydrogen Sulfide

   1. Lead Acetate Paper - Moisten filter paper with a five percent (by weight) solution of lead acetate and expose for 5 minutes to the atmosphere under test. A color varying from gray through brown will indicate very low concentrations of hydrogen sulfide. If the moistened paper remains colorless, no hydrogen sulfide is present.

   2. Hydrogen Sulfide Ampoules - These ampoules utilize a solution of lead acetate which is absorbed by the cloth covering and darkens on exposure to the gas when the ampoule is crushed. A comparing color scale is provided giving the concentration of gas present by volume. The ampoules should be exposed to the atmosphere under test for one minute only and the reading made immediately.

   3. Hydrogen Sulfide Detector - A sample of the atmosphere under test is brought in contact with a detector tube using a sampling hose and aspirator. The amount of discoloration in the detector tube is compared with a graduated scale giving the percentage of hydrogen sulfide present.

c. Combustible Gas Indicators - A common type consists of a battery operated unit, which oxidizes or burns a sample of the atmosphere to be tested over a heated catalytic filament which is part of a balanced electrical circuit. Combustible gases in the sample are burned on the hot wire, thus raising its temperature and increasing its resistance in the samples. The unbalancing of the electrical circuit causes the deflection of the meter pointer, which indicates on a scale the concentration of combustible gases or vapors in the sample. This scale is graduated in percentage of the lower explosive limit.

A tabulated list of equipment for the detection of various gases and oxygen deficiency is presented in Table 13-1.

13-4 RESCUE PRACTICES

a. Gas Rescue Techniques

An adequate crew is a necessity. One should never enter a manhole or tank to effect a gas rescue without a hose mask or compressor air mask. Many have bravely but foolishly attempted rescues without the necessary respiratory protective equipment. The rescuer must not breathe the gas himself even for a short time. No one is immune to the action of noxious gases or oxygen deficiency. The well-intentioned rescuer, who walks into an atmosphere of gas and succumbs, gives no assistance to the original victim and merely adds to the work of subsequent rescuers. His action is similar to the common occurrence where a man, who himself cannot swim, jumps into the deep water because he sees another man drowning. Such procedures are not heroic; they are ridiculous. There are indeed occasional conditions in which it is possible to enter a short distance into air contaminated with gas and to drag out an unconscious man; but the rescuer should not attempt this without having a line tied around him and held by someone outside. It is usually wiser to open the doors and windows from the outside, and to allow fresh air to sweep the gas from the room before the rescue is made.

TABLE 13-1

METHOD FOR DETECTION OF VARIOUS GASES AND OXYGEN DEFICIENCY

GAS VAPOR	METHOD FOR DETECTION
Hydrogen Sulfide	Lead acetate impregnated paper (qualitative) Hydrogen sulfide ampoules Hydrogen sulfide detector (quantitative)
Methane	Combustible gas indicator Oxygen-deficiency indicator Methane alarm
Carbon Dioxide	Oxygen-deficiency indicator
Nitrogen	Oxygen-deficiency indicator
Oxygen depletion	Oxygen-deficiency indicator
Carbon Monoxide	Carbon monoxide indicator Carbon monoxide detector set Carbon monoxide N.B.S. tube (quantitative)
Hydrogen	Combustible gas indicator Oxygen-deficiency indicator
Gasoline	Combustible gas indicator Oxygen-deficiency indicator for concentrations over 0.3 percent
Chlorine	Aqueous ammonia Odor
Ammonia	Odor
Sulfur Dioxide	Odor Sulfur dioxide gas detector
Ethane	Combustible gas indicator Oxygen-deficiency indicator

b. Chlorine Poisoning

Certain approved procedures for treating chlorine poisoning are as follows:

1. Remove the affected person at once to the open air and away from all gas fumes.
2. Place the patient flat on back.
3. The person affected should resist as much as possible the impulse to cough.
4. A physician should always be called.
5. If victim is unconscious and not breathing, use mouth-to-mouth resuscitation.
6. Splashes of liquid chlorine and chlorinated water destroy clothing, and if such clothing is next to the skin, it will produce irritation and acid burns.

c. First Aid and CPR

Following an accident, such as gas collapse, drowning, electric shock or other medical emergency, the three (3) emergency action steps (Check, Call, Care) should be employed as soon as possible.

Check:

The scene, to see if it is safe

The victim (breathing, pulse, injuries)

Call:

Emergency Medical Services (EMS), 911

Care:

Rescue Breathing

CPR

First Aid for injuries

Seconds count in a medical emergency. The interval between the stopping of the heart after the lungs cease to function is at most only ten minutes and often six minutes or less. The objective of CPR is to circulate oxygen containing blood to the brain and other vital organs until medical help arrives. Once started, CPR should be continued until the victim begins breathing on their own or until relieved by medical personnel.

All personnel should be trained in basic first aid and CPR through programs such as those offered by the American Red Cross. Once trained, personnel should be required to participate in practice drills on a regular basis. American Red Cross publications “Community First Aid and Safety” and “Workplace Training, Standard First Aid and CPR” should be obtained and maintained on file at each facility. These publications provide detailed instructions on providing CPR and basic first aid.

CHAPTER 14

INTRODUCTION TO WASTEWATER LABORATORY

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CHAPTER 14

INTRODUCTION TO WASTEWATER ANALYSIS

14-1 PURPOSE

The physical, chemical and biological analysis of wastewater is a tool used by the operator to evaluate, manipulate and control conditions within the treatment plant system. Accurate analytical results are the most useful information that an operator has to assure both permit compliance and effective treatment. For this reason, it is important that each operator has a basic knowledge of analytical procedures. Even when samples are collected and/or analyzed by an outside or contract laboratory, a basic understanding of analytical principles will aid the operator in evaluating and using this data.

Many people have a fear or phobia when it comes to working in a laboratory. They may feel that it is too complicated or they may be intimidated by the various chemicals, equipment and apparatus in the lab. It is hoped that the information contained in this chapter will ease these fears and will provide the basic knowledge needed to increase the operators confidence in a laboratory setting. The information contained herein is basic in nature and SHOULD NOT BE CONSIDERED A COMPREHENSIVE LABORATORY MANUAL. Since most people are somewhat familiar with many functions in a kitchen, this discussion will focus on the similarities between a kitchen and a laboratory. In a kitchen, the key to success is the addition of accurately measured ingredients in the proper sequence, under the proper conditions. Basic cleanliness is a must. The exact same things are true in the laboratory.

14-2 PROCEDURES (RECIPES)

In a kitchen, the first item needed is a recipe, which usually is taken from a cookbook. Once a person has that, he or she simply follows the instructions carefully. In the laboratory, the cookbook is called "STANDARD METHODS FOR THE EXAMINATION OF WATER AND WASTEWATER" or EPA'S "METHODS FOR CHEMICAL ANALYSIS OF WATER AND WASTES" (Exhibit 14-1). One should simply follow the instructions carefully.

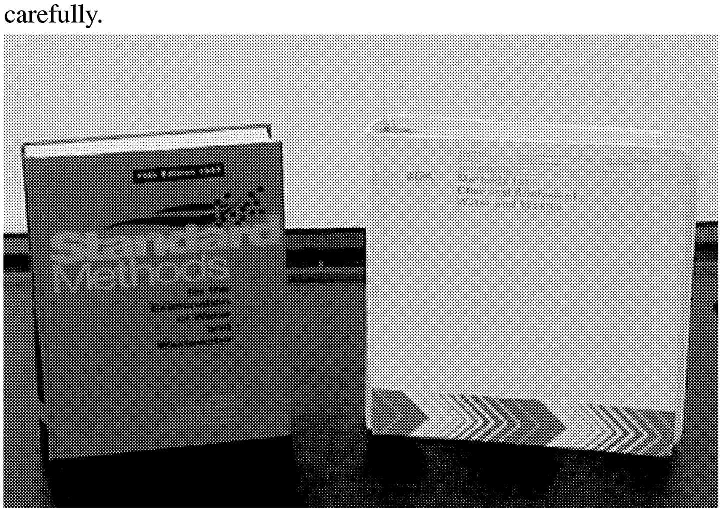


EXHIBIT 14-1

STANDARD METHODS AND EPA METHOD FOR CHEMICAL ANALYSIS OF WATER AND WASTEWATER

The methods manual is the most important piece of equipment in a lab. Every lab should have a copy of each of these manuals. Just like any cookbook, these manuals contain several procedures (recipes) for any given analysis. Therefore it is important to note that EPA approved methods should be used for all analyses. The listing of EPA approved procedures can be found in the CODE OF FEDERAL REGULATIONS, 40 CFR, PART 136.

14-3 GLASSWARE (UTENSILS)

In the kitchen, a variety of utensils, pots, pans, bowls, spoons, knives, measuring cups, etc., are used. These are used for measuring, mixing and cooking. In the laboratory, various pieces of glassware (beakers, flasks, cylinders, etc.) serve the same function. Laboratory glassware comes in many shapes and sizes and serve a wide variety of functions.

It is advisable, when purchasing glassware, to buy either PYREX or KIMAX since either will withstand the changes in temperature that often occur in analytical procedures. Figure 14-1, shows some of the more common types of glassware found in a lab.

a. Types of measurements

Accurate measurements are very important in both the kitchen and the laboratory. If the ingredients aren't measured properly, the end product will not be what is desired, whether it is a flavorful dish or an accurate determination.

In the kitchen and the lab, there are three (3) basic types of measurements;

1. VOLUMES
2. WEIGHTS
3. TEMPERATURE

In the kitchen, these measurements are usually made using the English system of weights and measures, while laboratory measurements are made using only the Metric system. Using this system, there are only two (2) conversions that must be remembered;

1. 1 liter (l) = 1,000 ml
2. 1 gram (g) = 1,000 mg

Volumes in the lab are always measured in either liters or milliliters. Weights are always measured in grams or milligrams. Temperature is always measured in degrees centigrade (Celsius).

b. Volumes

In both the kitchen and the lab, the most common type of measurement is volume. In the kitchen, cups, spoons and teaspoons are common measuring utensils. In a lab, graduated cylinders and pipets replace the cups and spoons. These are much more accurate and easier to use. Sometimes, in the lab, an unknown volume of reagent (ingredient) must be added to obtain a certain end point. This is called titration, and the volume of reagent added must be known or measured after the titration. A buret is used for such measurements. For very accurate measurements, volumetric flasks and pipets are used. With volumetric glassware each piece is specific for a set or particular volume of liquid. A consideration when measuring liquid volumes is that when water is placed in most containers, it tends to cling to the sides of the container and rises slightly around the edges. This gives a curved, distorted surface to the water. This surface is called the meniscus, Figure 14-2. When reading the level of water in a container, the bottom

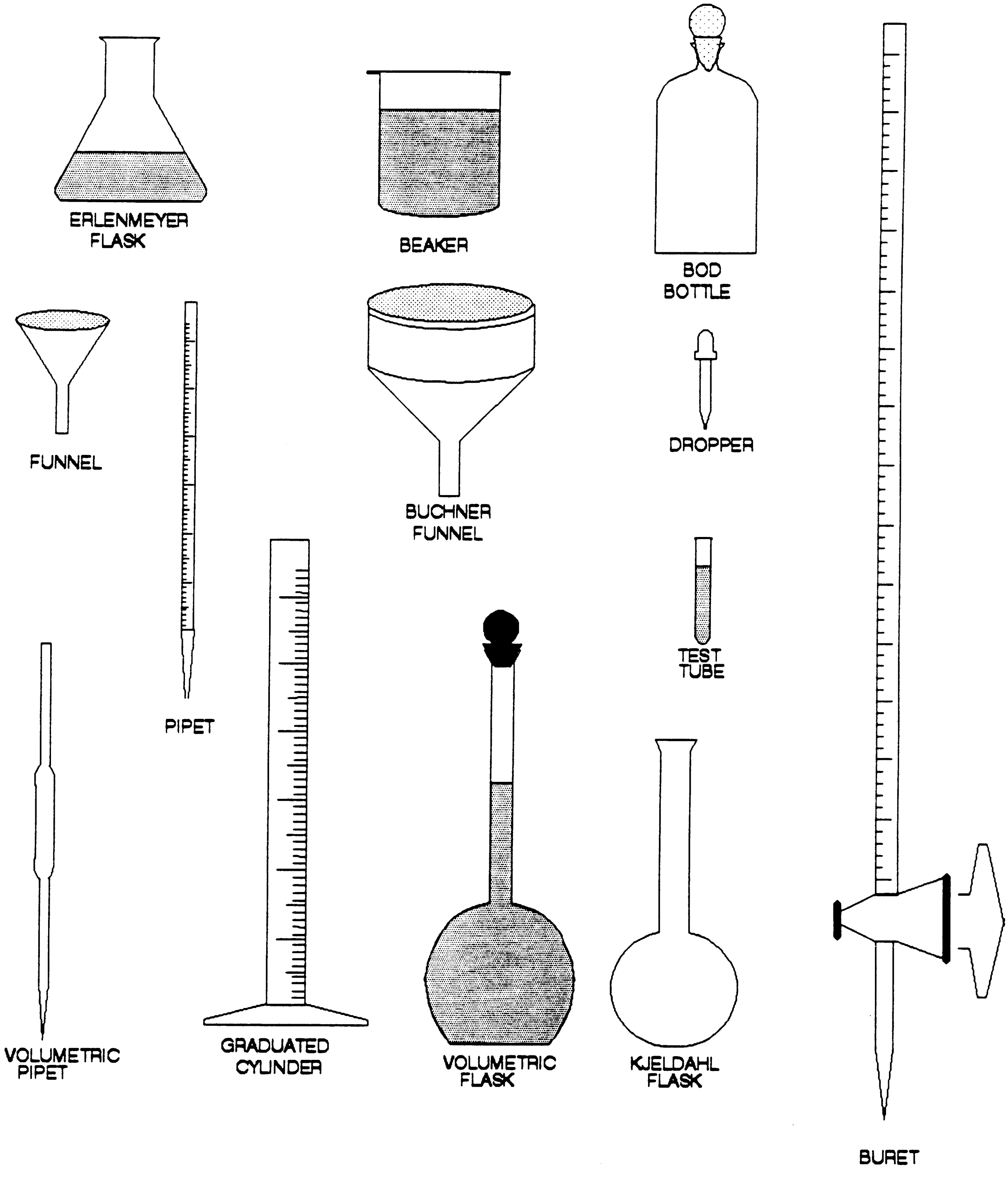
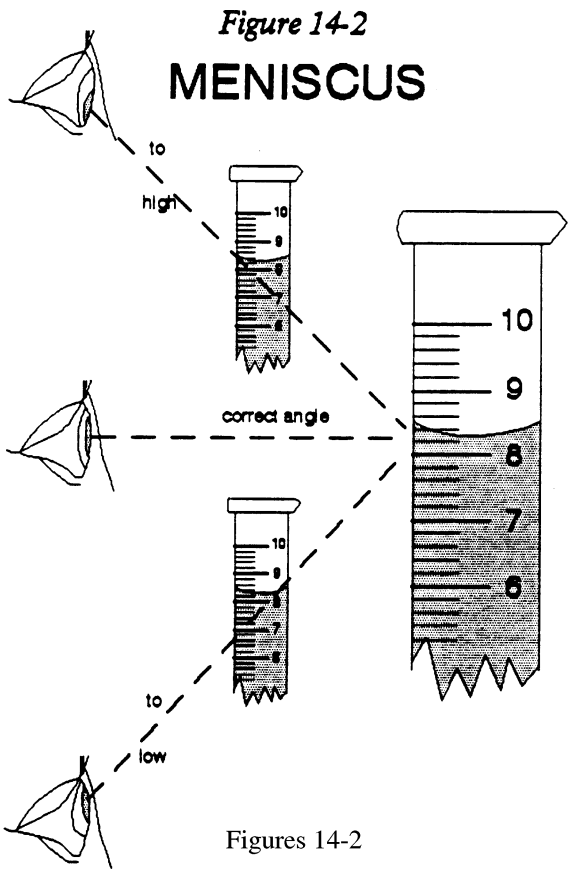


Figure 14-1

COMMON GLASSWARE



Figures 14-2
Meniscus

or lowest point on the meniscus is always taken as the point of reference.

c. Volumetric Glassware

When extreme accuracy is needed, volumetric glassware must be used. These devices are designed to deliver a precise amount of a single volume. This type of glassware consists of volumetric flasks, transfer (volumetric) pipets and burets.

1. Flasks

Volumetric flasks are calibrated to either contain or deliver a certain volume and have a single mark (graduation) etched on the neck of the flask. The flasks that deliver specific volumes are the most commonly used and most accurate. Typical sizes of volumetric flasks include; 1000, 500, 250, 100, 50, 25 and 10 ml. These are often provided with ground glass or plastic stoppers to prevent the contents from spilling when the contents are mixed.

2. Pipets

Pipets are of three general categories; volumetric (also called transfer), measuring (serological or Mohr), and dropping. Volumetric pipets have an enlarged bulb at the center and are calibrated to deliver a single fixed volume. They are used for precise work and their tolerance limits are specified by federal standards. Measuring or Mohr pipets are narrow straight tubes graduated to deliver variable amounts of liquid. They are not as accurate as volumetric pipets and should not be used when accuracy is critical. Dropping pipets are like a medicine dropper. In the lab, they are used to adjust the strength of a solution when it is not important to know the volume required, as in pH adjustments.

3. Burets

Burets are designed to dispense definite (measured) volumes and are made from accurate-bore glass tubing with glass or Teflon stopcocks and capillary tips of specific sizes. The most common burets are those having 25 ml and 50 ml capacities. Other types, such as large (100 ml), micro-burets, auto-refill burets and electronic burets that pump and display volumes, are also available.

d. Glassware Specifications

Federal specifications have been established for volumetric glassware and are listed in the National Bureau of Standards, Circular 602, “Testing of Glass Volumetric Apparatus”. Glassware which meets the NBS specifications is designated as CLASS A, and all such items display a permanently marked “A”. These items must also indicate the calibrated capacity of the vessel, the temperature at which the calibration was made and whether the vessel is designed to contain or deliver the specified volume (indicated as either TC or TD).

All "glassware" need not actually be glass. Plastic, Teflon, porcelain and metal have been used as satisfactory substitutes for some uses and may even be preferred for particular applications. Teflon stopcocks have nearly replaced glass because they require no lubrication. Laboratory bottles, graduated cylinders, beakers and flasks are made from high quality plastic. They are clear, shatter-proof and can be autoclaved. Plastics should not be used with organic based liquids such as acetone and alcohols.

14-4 WEIGHTS

In a kitchen, the actual weighing of ingredients is rare and when required is usually accomplished with an inexpensive spring scale. In the lab, the measurement of weights is a common occurrence and must be carried out in a precise and accurate manner. With weights, like volumes, there are different degrees of accuracy required. Sometimes only approximate weights are required. Such weights will be specified to the nearest gram or tenth (0.1) of a gram or occasionally to one hundredth (0.01) of a gram. For these measurements, a double-pan, triple beam, centigram or top loading electronic scale is acceptable.

Many times, however, measurements to the nearest ten thousandths (0.0001) of a gram are required. When this greater accuracy is required, an analytical balance should be used. An analytical balance should have a capacity of at least 200 grams and accuracy to the nearest one ten-thousandth (0.0001) of a gram (0.1mg).

Older analytical balances are mechanical, employing counterweights and knife edges to support the balance beam. Modern analytical balances are electronic and use microprocessor chips to perform the analytical function. Either type is capable of doing an excellent job if properly placed, operated and maintained.

All balances should be calibrated daily using a Class S-1 set of weights. Normally, calibration with a 1 gram and a 100 gram weight is sufficient.

Analytical and top loading balances should be serviced and calibrated by a factory trained technician at least once per year. This service should be recorded and attached to the balance. Some precautions to ensure accuracy include:

1. **PROPER LOCATION** - Away from air currents or vibration, away from direct sunlight or heat, away from moisture or chemicals, placed on sturdy table, must be level.
2. **USING THE BALANCE** - Zero the balance prior to each use. Use forceps to handle weights and objects or containers to be weighed.

14-5 SAMPLING

a. General

The value of any laboratory result depends on the integrity of the sample. Analytical results, therefore, can be no better than the sample used. The object of sampling is to collect a portion of the wastewater small enough to be handled in the lab, yet representative of the wastewater from which it was collected. It must be collected in such a manner that nothing is added or lost in the portion collected and no change occurs between the collection and the laboratory analysis. Unless these conditions are met, laboratory results may be misleading.

The precise location of sampling points and the collection procedures will vary from plant to plant. The following guidelines for sample collection should be observed:

1. The sample should be well mixed. This, typically, is where the wastewater flow is turbulent. It generally is taken from a tap on the pump discharge, as it free-falls from a pipe, or just before flow enters a transfer pipe from a tank or basin.
2. Large particles should be avoided. Raw wastewater should be sampled after screening if possible.
3. No deposits, growths or floating materials that have accumulated at the sampling point should be included.
4. Samples should be analyzed as soon as possible. If samples are to be held for longer than one hour, they should be chilled to 4˚C until analyzed.
5. Sampling points should be readily accessible, proper equipment should be on hand, and all safety precautions should be observed.
6. The collection of any sample must be properly documented. This means that a permanent record must be kept of the date and time the sample was collected, the sampling point and who collected the sample. In addition, this information should be included on a label affixed to the sample container.
7. Sample preservation may be necessary for some chemical constituents. The accepted preservatives and holding times for the various constituents are listed in Table 14-1.

b. <u>Sample Containers</u>

Care must be taken to see that the proper sample container is used. For most wastewater samples, plastic sample bottles are preferred. Samples collected for certain constituents require glass or amber colored glass and some require foil lined caps. Acceptable containers are listed in Table 14-1.

c. <u>Sample Preservation</u>

Many wastewater parameters can change rapidly once placed in a container. For this reason, it is always better to analyze samples as quickly as possible after collection. When this is not possible, the sample must be preserved. Placing the sample on ice or refrigeration is the most common preservation technique.

Adjustment of the sample pH using sulfuric or nitric acid is also very common. Additional preservatives and maximum holding times for common wastewater parameters are listed in Table 14-1.

d. <u>Types of samples</u>

There are two basic types of samples that may be collected, grab samples and composite samples. A grab sample consists of a single sample collected at one point in time. A composite sample is a series of grab samples combined into a single (composite) sample. Composite samples are usually equal portions collected at fixed intervals for a certain period of time (usually 24 hours). Composite samples may also be collected with the volume proportional to the amount of flow. In either type composite sample, the portions are mixed to produce a final representative sample. Certain parameters require grab samples. Examples include dissolved oxygen, pH, residual chlorine, fecal coliform and oil and grease.

Composite samples are generally more representative of the character of the wastewater over a period of time. Compositing eliminates the effects of intermittent changes in strengths and flow. Portions of sample should be collected at intervals of one hour or less. A minimum volume of 120 mls should be collected with each collection. Composite samples are usually collected with automatic sampling equipment, but may be collected manually. When using automatic equipment, care should be taken to ensure that tubing and containers are clean, and that the sampler purges itself between samples. Ice should be placed in non-refrigerated samplers to keep the samples chilled during collection. Holding times begin at the end of the compositing period.

TABLE 14-1

RECOMMENDED CONTAINERS, HOLDING TIMES, & PRESERVATION

PARAMETER	CONTAINER	PRESERATIVE	VOLUME REQUIRED	HOLDING TIME
BIOLOGICAL				
Coliform, Fecal	Sterile P or G	Chill + 0.008% Thio	500 ml	6 Hours
Toxicity	P	Chill	1 – 2 Gallons	48 Hours
INORGANIC				
Acidity	P or G	Chill	500 ml	14 Days
Alkalinity	P or G	Chill	500 ml	14 Days
Ammonia	P or G	Chill + H2SO4	500 ml	28 Days
BOD	P or G	Chill	500 ml	48 Hours
COD	P or G	Chill + H2SO4	500 ml	28 Days
Chloride	P or G	Chill	500 ml	28 Days
Chlorine, Residual	P or G	Chill	100 ml	Immediate
Color	P or G	Chill	250 ml	48 Hours
Cyanide, Total	P or G	Chill + NaOH (Ascorbic)	500 ml	14 Days
Cyanide, Ammenable	P or G	Chill + NaOH (Ascorbic)	500 ml	14 Days
Fluoride	P	NONE	500 ml	28 Days
Hardness	P or G	CHILL + HNO3	500 ml	6 Months
Metals	P or G	CHILL + HNO3	500 ml	6 Months
Nitrogen, Total Kjeldahl	P or G	Chill + H2SO4	1000 ml	28 Days
Nitrogen, Nitrate	P or G	Chill	500 ml	48 Hours
Nitrogen, Nitrate + Nitrite	P or G	Chill + H2SO4	500 ml	28 Days
Nitrogen, Nitrite	P or G	Chill	500 ml	48 Hours
Nitrogen, Organic	P or G	Chill + H2SO4	1000 ml	28 Days
Oil & Grease	G	Chill + H2SO4	1000 ml	28 Days
Organic Carbon	P or G	Chill + H2SO4	500 ml	28 Days
Oxygen, Dissolved		NONE		Immediate
pH (Hydrogen Ion)	P or G	NONE	100 ml	Immediate
Phenols	P or G	Chill + H2SO4	1000 ml	28 Days
Phosphate, Ortho	P or G	Filter + Chill	500 ml	48 Hours
Phosphorus, Total	P or G	Chill + H2SO4	500 ml	28 Days
Solids, Total	P or G	Chill	500 ml	7 Days
Solids, Dissolved	P or G	Chill	500 ml	7 Days
Solids, Suspended	P or G	Chill	500 ml	7 Days
Solids, Settleable	P or G	Chill	500 ml	48 Hours
Solids, Volatile	P or G	Chill	500 ml	7 Days
Sulfate	P or G	Chill	500 ml	28 Days
Sulfide	P or G	ZnAcet + NaOH	500 ml	7 Days
Sulfite	P or G	Chill	500 ml	Immediate
Surfactants	P or G	Chill	1000 ml	48 Hours
Temperture		NONE		Immediate
Turbidity	P or G	Chill	500 ml	48 Hours
ORGANIC				
Volatile Organics (VOC)	G (VOC Vials)	DeCl & Chill	40 ml vial	7 Days
Extractable Organics	G	Chill	1000 ml	7 Days
Pesticides/Herbicides	G	Chill	1000 ml	7 Days

14-6 GENERAL

a. Chemicals and Reagents (Ingredients)

In the kitchen the ingredients are numerous and varied. The ingredients in the lab are chemicals and mixtures of chemicals called reagents. These chemicals, like the ingredients in a kitchen, must be handled carefully. Some can be stored on a shelf, some must be refrigerated, and some must be kept away from other chemicals. As in the kitchen, care should be taken to avoid contamination.

The following are some guidelines for handling and using reagents:

1. Use only those chemicals or compounds described in the procedure (recipe).
2. Use high grade, best quality chemicals, ACS or analytical grade.
3. Cleanliness is the key. Avoid contamination from using dirty glassware.
4. Use commercially prepared reagents when possible.
5. Be aware of shelf life and do not order large quantities.
6. Date all chemicals and reagents upon arrival and when opened.
7. Properly dispose of outdated chemicals.
8. Avoid dangerous violent reactions by precisely following the recommended procedures.
9. All chemicals for the preparation of standards, calibration solutions, and titrants should be dried at 105 degrees C overnight and maintained in a desiccator until it reaches room temperature prior to use.

b. Temperature

Temperature in the lab is measured using mercury filled thermometers or electrical devices. The thermometers used should be graduated in intervals of no more than 0.1˚C. The accuracy of all temperature measuring devices should be checked (calibrated) against a NBS traceable thermometer. A "traceable" thermometer is one that is certified to be accurate with it's calibration traceable back to the National Bureau of Standards. General purpose thermometers should be checked over the entire temperature range. Thermometers used for single purposes, such as in a BOD incubator, need only be calibrated at the desired temperature.

When thermometers are used in incubators, care should be taken to see that the temperature can be read without temperature fluctuations when the door is opened. In low temperature incubators, the thermometer should be kept in a beaker of water. In high temperature incubators, a beaker of fine sand serves the same purpose.

Critical temperatures (those in incubators, water baths and ovens) should be documented daily and the data maintained as a permanent record.

c. Water

Whether in the kitchen or in the laboratory, water is the most frequently used and most important ingredient (chemical). The sensitivity of some of the tests are sufficient to detect the smallest traces of contamination. Therefore, it is important to use only the highest quality distilled water.

Distillation will not remove certain contaminants such as ammonia or carbon dioxide. To remove ammonia, distilled water should be passed through a mixed bed ion-exchange column. Carbon dioxide is rarely a problem for wastewater analyses.

While distilled/deionized water is suitable for most wastewater analyses, some procedures require a higher quality water. This higher quality water can be obtained by passing distilled/deionized water through a sub-micron filter. Commercial systems employing this treatment as well as reverse osmosis followed by ion exchange are available. Regardless of how the laboratory's pure water is prepared , it should be routinely tested to ensure it's purity.

Some things to remember about water used in the lab are:

1. Distilled/deionized water stored in plastic will absorb organics through the plastic.
2. Water stored in glass for long periods can leach soluble materials from the glass.
3. Drug store or grocery store distilled water generally produces unsatisfactory results.

d. Laboratory Cleaning and Sterilization

A clean container is usually defined by the layman as one which is visibly free from dirt or foreign materials. However, in the lab, the cleaning agent used might leave a film on the container that could cause erroneous results. Since many cleaning solutions are not bactericides, a visibly clean piece of equipment does not mean that the equipment is free of microorganisms. All glassware and equipment used in the lab should be washed with a laboratory grade detergent and triple rinsed with distilled water.

e. Reporting of Results

Most chemical analyses of wastewater are reported in mg/l or parts per million(ppm). For our purposes, these two terms are the same. Notable exceptions to this are pH, reported in standard units (SU), Fecal Coliform (col./100 ml) and conductivity (umhos).

Results of any analyses should be recorded immediately and the only numbers reported should be "significant figures". Significant figures refer to numbers that are well within the tolerance for error of any given analysis. For example, if one gets a result of 120.5 mg/l for a BOD and the margin for error is 10-15%, it would be reported as 120 mg/l. However, if you ran an ammonia analysis, which produces much more precise results, and the result was 1.86 mg/l, all these digits would be reported. In most instances rounding to the nearest mg/l will be sufficient.

14-7 SAFETY

Many of the techniques employed in the lab can be learned by observation and practice. However, extreme caution should be exercised when working in a lab since many of the chemicals used may be harmful to eyes, skin and the respiratory system. The most important thing is to practice safety. The following are some safety rules which should always be followed:

1. When adding acid to an aqueous solution, let the acid flow down the side of the receiving container slowly. **Never add water to acid.**
2. When pipetting any material, use a pipet bulb. All chemicals should be considered toxic. **Never pipet with your mouth.**
3. If glassware slips, let it fall. An attempt to catch falling glassware might result in a dangerous cut.
4. Properly label all reagents.
5. Do not sniff the mouth of a container to determine it's contents.
6. To neutralize strong acid on skin or clothing, wash with tap water and apply dilute ammonium hydroxide or baking soda. Wash with large amounts of water.

7. To neutralize a strong alkali or base chemical on skin or clothing, wash with tap water and apply dilute acetic acid (vinegar). Wash with large amounts of water.
8. If any chemical gets in the eyes, wash with large amounts of water and see a physician immediately.
9. Keep the proper types of fire extinguishers in key areas.
10. Wear protective clothing and shoes.
11. Keep a properly equipped first aid station accessible at all times.
12. Wear safety glasses.
13. Smoking, eating and drinking in the lab should not be permitted. Never use laboratory vessels to hold food or beverage.
14. Store chemicals according to compatibility, at no higher than eye level.

14-8 COMMON WASTEWATER ANALYSES

There are hundreds of various tests or analyses that can be done on wastewater, but only a few are common to almost any size or type of treatment system. The following pages contain a brief description of these more common tests.

a. pH

The accurate measurement of pH is of extreme importance to the wastewater plant operator. It is not only critical as an analytical test for wastewater operations and reporting, it is important in preparing many reagents and buffers, and is used in other chemical measurements such as alkalinity and carbon dioxide.

pH, simply defined, is the hydrogen ion activity or the intensity of the acidic or alkaline character of a solution. A logarithmic scale is used as the pH of aqueous solutions. Temperature is a critical factor affecting pH determinations.There are, simply stated, two ions which cause pH intensity, the Hydrogen ion (H+) and the hydroxyl ion (OH-). The (H+) ion causes acidic conditions and the OH- ion causes alkaline conditions. At 25˚C , a pH of 7.0 is neutral and the activities of the H+ and OH- ions are equal. Natural wastes usually have a pH in the range of 4 to 9. Domestic wastewater typically has a pH between 6 and 9. pH values range from 0 - 14, with any value less than 7 considered acidic and values greater than 7 considered basic or alkaline.

ACIDIC ALKALINE

0——————7——————14

NEUTRAL

Measurements for pH are determined electrometrically using a pH meter and electrode. The meter responds to the activity of hydrogen ions by potentiometric response of a glass electrode and a reference electrode. pH meters reproducible to plus or minus (±) 0.1 pH units with a range of 0 - 14 and equipped with a temperature compensation adjustment should be used. Separate pH and reference electrodes or combination electrodes can be used. For most wastewater applications, combination electrodes are preferred.

The reference electrode is filled with an electrolyte, normally a potassium chloride (KCL) solution. Most manufacturers make a sealed electrode using a gelled electrolyte. Care should be taken to see that these electrodes are filled to the proper level with the proper electrolyte solution. The electrode junction should also be wetted. Electrodes that have been stored dry should soak for 24 hours in a pH 7 buffer prior to use.

The key to accurate pH measurements is the precise calibration of the pH meter against known standards. Commercially prepared standards are preferred. Three standards should be on hand for these calibrations; pH 4, pH 7, and pH 10.

Always follow the manufacturer's instructions for the pH meter being used. Electrodes should be stored in a pH buffer, never in distilled water. The following are the proper procedures for calibrating a typical ph meter:

1. Remove the electrode from the storage solution and rinse with deionized or distilled water.
2. Gently dry the electrode with lab towels or wipes.
3. Use two buffers for daily calibration.
4. Be sure buffers and sample are at the same temperature.
5. Calibrate using the pH 7 buffer first. (Immerse the electrode into fresh 7 buffer, allow the meter to stablize and calibrate according to the manufacturer's instructions.)
6. Rinse electrode with distilled or deionized water.
7. Blot dry with lab towel or wipe.
8. Calibrate using either pH 4 or pH 10 buffer, depending on the estimated pH of the sample. (Immerse the electrode into the 2nd buffer, allow the meter to stablize and calibrate according to the manufacturer's instructions.)
9. Follow the manufacturer's instructions to calibrate on the 2nd buffer, (for older meters you may have to use slope adjustment or temperature adjustment for second calibration). The double buffer calibration should be performed with fresh buffer daily.

b. Dissolved Oxygen

Dissolved Oxygen (D.O.) is probably the single most valuable analytical determination performed by an operator of an aerobic wastewater facility. Dissolved Oxygen, as the name implies is the amount of oxygen dissolved in water. This is free, uncombined oxygen that is available to aquatic, aerobic plants and bacteria as well as gill breathing animals.

Dissolved oxygen levels in water and wastewater are dependent on the physical, chemical and biological characteristics of the particular body of water. Oxygen is a highly reactive gas that is added to the water column by:

1. Mixing with air (Aeration)
2. Chemical reduction reactions
3. Photosynthesis reactions of aquatic plants

In aerobic wastewater treatment facilities improperly maintained levels of D.O. will cause poor treatment and odor problems.

Mississippi State Law requires a minimum D.O. level of 4.0 mg/L in state streams. NPDES Permits for all treatment facilities require a minimum D.O. in the effluent of 6.0 mg/L.

The solubility of oxygen in water (the amount of oxygen that can be dissolved in water) is dependent on the temperature and the barometric pressure of the atmosphere. In Mississippi, only the temperature needs to be considered. There are no streams greater than 600 feet above sea level; therefore, the barometric pressure is not a factor. The lower the temperature of the water, the higher the solubility of oxygen. Conversely, the higher the temperature of the water, the lower the solubility of oxygen. This is demonstrated on Table 14-2 on Page 14-14.

There are two basic methods for analyzing D.O., the Winkler Titration method and the Membrane Electrode method. Both methods are accurate and are acceptable for NPDES monitoring purposes. The Winkler method requires accurate mixing and maintenance of several chemicals, the proper collection of samples and the absence of interfering materials. The Membrane Electrode requires proper calibration, but eliminates the need for sampling and most interferences. For these reasons the Membrane Electrode method has all but replaced the Winkler method and is the only method discussed further in this chapter.

A properly designed and engineered Dissolved Oxygen Meter and membrane covered polarographic electrode provide an excellent method for D.O. analysis and offer several advantages over the Winkler method. Some of the advavantages of the meter and probe include:

1. Eliminates most interferences,
2. Eliminates the need for several reagents,
3. Eliminates handling dangerous sulfuric acid,
4. Can be used on site, eliminating the need for sampling,
5. Can be used for continuous monitoring,
6. Can be used in highly colored wastes or wastes with high solids.

The use of the meter and probe is recommended, especially for industrial wastes and municipal systems that receive industrial wastes. Acceptable units should employ a membrane covered polarographic sensor or electrode connected to a meter with a minimal 0-20 mg/l scale. Either analog or digital meters are acceptable.

The keys to obtaining accurate reliable results with a meter and electrode are adequate maintenance and frequent and proper calibration.

Proper maintenance includes:

1) replacing the membranes and filling solution periodically (following manufacturer's instructions),
2) keeping the gold cathode bright and untarnished
3) and storing the probe in a moist environment.

Calibration can be accomplished by one of three methods; saturated water, moist air or Winkler titration. Regardless of the method used, calibration should be performed each day.

c. Biochemical Oxygen Demand

Biochemical Oxygen Demand or BOD is one of the most important characteristics of wastewater because it is one of the best indicators of wastewater strength. It is a measurement of the amount of oxygen required for the biochemical breakdown of organic matter at a given time and temperature. To determine the total BOD, an incubation period of several weeks would be required. Therefore, in the interest of uniformity, the 5 day BOD at 20°C has become the standard analysis to determine the organic strength of wastewater. The BOD of domestic wastewater will usually vary between 100 and 300 mg/l.

TABLE 14-2

D. O. SOLUBILITY CHART

TEMPERATURE ˚C	DISSOLVED OXYGEN PPM (mg/l)	TEMPERATURE ˚C	DISSOLVED OXYGEN PPM (mg/l)
0	14.6	23	8.7
1	14.2	24	8.5
2	13.9	25	8.4
3	13.5	26	8.2
4	13.2	27	8.1
5	12.8	28	7.9
6	12.5	29	7.8
7	12.2	30	7.7
8	11.9	31	7.5
9	11.6	32	7.4
10	11.3	33	7.3
11	11.1	34	7.2
12	10.8	35	7.1
13	10.6	36	7.0
14	10.4	37	6.8
15	10.2	38	6.7
16	9.9	39	6.6
17	9.7	40	6.5
18	9.5	41	6.4
19	9.3	42	6.3
20	9.2	43	6.2
21	9.0	44	6.1
22	8.8	45	6.0

BOD is a calculated value obtained by determining the dissolved oxygen (D.O.) prior to and following incubation of a sample and applying the dilution factor involved. The only analytical chemistry involved is the D.O. analysis previously discussed. The mathematical formula for calculating BOD mg/l is;

$$\text{BOD mg/l} = \text{Initial D.O.} - \text{Final D.O.} \times \frac{300}{\text{ml sample}}$$

As stated earlier, the methods for determining D.O. are the Winkler Titration and the Meter and Probe; the latter being the preferred method.

Certain precautions must be taken when preparing a sample for BOD analysis:

1. The sample must not contain residual chlorine. If there is residual chlorine, it must be dissipated prior to setting up the BOD. Leaving the sample container open for 3 to 4 hours will usually allow the chlorine to dissipate into the atmosphere. If it will not dissapate, sodium sulfite can be used to dechlorinate the sample.
2. The sample must not be supersaturated with oxygen. If the sample has a dissolved oxygen of more than 9.2 mg/l at 20˚C, it is supersaturated. Shaking a partially filled bottle of sample or bubbling air through it for several minutes will remove the excess oxygen.
3. The sample should not be of extreme pH. Samples should be neutralized to a pH of 6.5 to 7.5 with a weak sulfuric acid or sodium hydroxide solution.

The collection of the BOD sample must follow standard procedures. A composite sample will be most representative of the wastewater being analyzed. Samples should be analyzed as soon as possible after collection. Samples should never be held more than 48 hours. If the sample is to be held more than 2 hours, it should be refrigerated.

When a sample contains very few microorganisms as a result of chlorination, high temperature or extreme pH, it must be seeded with a heavy population of bacteria. Seeding simply introduces a biological population capable of stabilizing the organic matter in the wastewater. The standard seed material is settled domestic wastewater that has been stored at 20˚C for 24 to 36 hours. Recently, commercial seed materials such as Polyseed have been developed and approved for use. Procedures for seeding a sample should be in accordance with Standard Methods.

There are several critical factors which will affect a BOD analysis:

1. Good quality dilution water: Dilution water should not deplete more than 0.2 mg/l D.O. in 5 days. Blanks should be analyzed each time a BOD is performed to check the dilution water.
2. Accurate D.O. determinations: The Oxygen Meter with BOD Probe is the preferred method for conducting BOD analysis.
3. Proper incubation controls (light, time, temperature): Normal methodology calls for incubation at 20˚C + or - 1˚C for 5 days in the dark. Incubator temperature should be checked and recorded daily. Avoid excess light by keeping incubator door openings to a minimum.
4. Proper range of dilutions: To be accurate, a sample should deplete at least 2 mg/l and have at least 1 mg/l of D.O. left after incubation. Three dilutions per sample, properly spaced, will usually be sufficient. With domestic wastewater, good starting dilutions would be 0.5%, 1.0% and 5% for influent samples and 5%, 10% and 25% for effluent samples.

5. Proper technique (accurate volumetric measurements and avoiding contamination): Dilutions can be made into the BOD bottles or in 500 ml graduated cylinders. Use a wide bore pipet for less than 25 mls and graduated cylinders for larger volumes. To avoid contamination, wash BOD bottles as soon as possible with a good laboratory grade detergent. Rinse several times, at least 3 times with distilled water. Another way to reduce the likelihood of error is to use commercially prepared reagents. Order in small quantities and replace often.
6. Nitrification inhibition: There are two groups of materials in wastewater that cause biochemical oxygen demand. Carbon containing compounds create what is referred to as Carbonaceous BOD and Nitrogen containing compounds that create Nitrogenous BOD. If it is desired or required to determine either of these independently, inhibition of Nitrogen is required. This is accomplished by treating the sample with a chemical that inhibits the Nitrogen fixing bacteria. The chemical, 2-chloro-6 (trichloromethyl) pyridine is available, pre-mixed on an inert salt, from Hach Chemical Company.

d. Total Suspended and Volatile Suspended Solids

Total suspended solids (TSS) is a simple procedure requiring a minimal amount of equipment, space and expertise. The results give the operator a good idea of treatment efficiency as well as the effect of the wastes on the receiving stream. Because of this, the TSS analysis is required by practically every NPDES Permit issued by the state.

A review of current references will show that the term residue has, in many instances, been substituted for solids. For our purposes, however, we will continue to use the term suspended solids.

When sampling for TSS, care should be taken to avoid extraneous material such as sticks, leaves, fecal matter, etc. The sample should be taken 4 to 6 inches below the surface in a wide mouth container. Since there is no practical preservative for TSS the analysis should be completed as soon as possible after collection. In no case should the sample be held for more than seven days.

The following is a list of apparatus needed to conduct the vacuum filtration method for TSS and VSS:

1. Glass fiber filters, 4.7 cm, without organic binder
2. Filtration apparatus
3. Filtration manifold, 3 place or (filter flask, 1 liter)
4. Vacuum pump
5. Drying oven, 103 - 105˚C
6. Muffle furnace, 550˚C (for volatile solids)
7. Desiccator (with indicating desiccant)
8. Analytical balance, 200 gm capacity, 0.0001 gm sensitivity
9. Aluminum weighing dishes
10. Forceps (smooth tipped)
11. Vacuum tubing
12. Class S set of weights
13. Thermometer, 103 to 105˚C
14. Polyethylene wash bottles

To prepare the filters, they must be rinsed with distilled water, dried in the drying oven at 103 to 105˚C, and allowed to cool in the desiccator. It is common practice to prepare a number of filters and store them in the desiccator until needed. The weight of these filters is called the Tare weight.

Vacuum pressure is required to filter the solids. It is recommended that a vacuum pump be used. Water aspiration vacuum is usually too slow to effectively filter most samples and tends to leave solids on the filtration apparatus.

After the filters plus the residue have been dried for 2 hours at 103 to 105˚C, they (in the aluminum weighing dishes) are placed in the desiccator for 15 to 20 minutes. The weight of the dried filters plus the residue is called the Gross weight.

A balance capable of weighing to the nearest 0.0001 gm is required. Weighing the filter alone or in the aluminum weighing dish is acceptable. The accuracy of the balance should be checked and recorded daily using Class S weights.

The following formula is used to calculate TSS mg/l:

$$\text{TSS mg/l} = (\text{Gross Wt.} - \text{Tare Wt.}) \times \frac{1{,}000{,}000}{\text{ml sample}}$$

If it is desired to know the volatile (organic) content of the suspended solids, called Volatile Suspended Solids, VSS, the dried filter plus residue must be ignited in the muffle furnace for 30 minutes at 550˚C. After the ashed filter has been cooled in the desiccator, it is placed on the balance and weighed again. This weight is called the Ashed weight. The following formula is used to calculate VSS mg/l:

$$\text{VSS mg/l} = \text{Gross wt.} - \text{Ashed wt.} \times \frac{1{,}000{,}000}{\text{ml sample}}$$

In order to maintain proper analytical quality assurance, these suggestions should be followed as a minimum:

1. Check and record the temperatures of the oven and furnace daily. Calibrate thermometers against an NBS or ASTC certified thermometer.
2. Run duplicates on at least 10% of the samples.
3. Run a blank with every set of samples.
4. Dry or replace desiccant as needed (at least weekly).
5. Have someone reweigh 10% of the filters and record duplicate weights.
6. Have someone check all calculations, note any errors.

e. <u>Ammonia Nitrogen</u>

Ammonia is an essential nutrient in an aquatic system, as well as an important contaminant in wastewater discharges. Excess ammonia can lead to nuisance algae blooms, high oxygen demands, and in some instances, ammonia toxicity.

Ammonia can be analyzed by any of several methods. These include distillation/titrimetric, distillation/nesslerization, automated-phenate and specific ion electrode. Regardless of which method is used **distillation is required unless it can be demonstrated that it isn't needed**. Distillation is especially important if either the nesslerization or titration procedures are used. The most common methods employed in Mississippi wastewater labs are the nesslerization (colorimetric) method and the specific ion electrode method. For this reason, the focus of this discussion will be on these procedures.

Samples for ammonia determination should be analyzed as soon as possible after collection. If immediate analysis is not possible, a sample may be preserved for up to 28 days by adding a sufficient amount of sulfuric acid to lower the pH to less than 2 SU, followed by refrigeration. Normally, 5 mls of sulfuric acid per liter of sample is sufficient.

A number of organic compounds present in wastewater will cause turbidity when nessler reagent is added if it is not distilled. Volatile compounds such as acetone, aldehydes and alcohol may cause interferences. If these are present, sulfuric acid should be added to the sample until the pH is 2.5 SU followed by boiling for two minutes. Residual chlorine must be removed from the sample by adding 1 ml of sodium thiosulfate dechlorinating agent per mg/l of chlorine in 500 ml of sample before distillation.

For the distillation procedure, the sample is adjusted to pH 9.5 with sodium hydroxide or sulfuric acid. Once the desired pH is obtained, the sample is buffered with borate buffer. After buffering, the sample is distilled into boric acid solution. The ammonia-laden distillate can then be analyzed colorimetrically or titrimetrically, depending on the ammonia nitrogen concentration.

As stated earlier, one of the most common methods for ammonia determination at wastewater facilities in Mississippi is the colorimetric (nesslerization) method. Nessler reagent reacts with ammonia nitrogen to produce a yellow complex whose intensity is proportional to the concentration of ammonia. Interferences are effectively eliminated by distillation. The detection range using this method is from 0.4 mg/l to 5.0 mg/l. The major piece of equipment required is a spectrophotometer or colorimeter with a 425 nm wavelength filter installed.

Another common method for determining ammonia concentration is the specific ion electrode method. Since color and turbidity have no effect on the electrode, distillation may not be necessary. Distilled and non-distilled samples of the same waste should be analyzed to demonstrate distillation is not necessary.

The ammonia electrode is a gas detecting electrode which senses the level of dissolved ammonia in aqueous solutions. A hydrophobic gas-permeable membrane is used to separate the sample from the electrode internal solution. Dissolved ammonia in the test sample diffuses through the membrane until the partial pressure of the ammonia is the same on both sides of the membrane. For any aqueous sample, the partial pressure of ammonia is proportional to the ammonia concentration. Ammonia reacts with the electrode's internal solution to produce hydroxide ions. The potential of the electrode varies proportionally with the level of hydroxide ions, producing a signal which is indicative of ammonia concentration. The major pieces of equipment required are a good quality, direct reading specific ion meter and an ammonia electrode.

The key to obtaining accurate and reliable results using a meter and electrode is the proper maintenance of the meter and electrode and proper standardization with each analysis. Maintenance of the electrode consists of changing the membrane and filling solution whenever standardization cannot be achieved.

f. <u>Residual Chlorine</u>

Chlorine is added to wastewater to disinfect or kill disease causing organisms which pose a threat to human health. Although beneficial, chlorine produces many adverse effects. It reacts with organic compounds to produce small quantities of carcinogenic (cancer causing) compounds. Additionally, if the concentration is too high, it can kill not only harmful organisms, but useful organisms including fish in the receiving stream. For these reasons, it is important that the amount of chlorine remaining in the wastewater after disinfection be accurately monitored.

The analysis used to monitor the residual chlorine is called Total Residual Chlorine. This analysis measures the amount of free (uncombined) chlorine as well as the combined chlorine (chloramines).

There are several methods for determining total residual chlorine. These include:

1. Amperometric Titration
2. Iodometric Titration I and II
3. DPD Ferrous Titrimetric Method
4. DPD Colorimetric Method
5. Specific Ion Electrode Method

There are advantages and disadvantages to each method. Because of the equipment required and the complexity of the other procedures, the DPD Colorimetric method is by far the most common method used in wastewater plants in Mississippi. For this reason, the DPD Colorimetric method will be the only method discussed in this chapter.

Chlorine is a highly reactive gas that quickly combines with other chemicals, is liberated to the atmosphere and is reactive with pH and sunlight. Because of this, residual chlorine must be analyzed as quickly as possible after sample collection, preferably within 5 to 15 minutes. Samples to be held longer than 15 minutes should be filled completely to the top with no air bubbles and chilled at 4 degrees C.

The DPD reagent (N,N-diethyl-p-phenylenediamine) in the presence of the iodide-ion reacts with total residual chlorine to produce color. The color is then determined using a spectrophotometer or colorimeter.

There are many manufacturers that make kits that use DPD chemistry. They have all proven acceptable provided a colorimeter or spectrophotometer is used and some form of active standardization is used.

The apparatus needed for this analysis is a spectrophotometer or colorimeter equipped with a 515-530 nm light filter. **Color wheels or cubes that use DPD and are held up to a light source and read visually are not approved for NPDES reporting purposes.**

g. Fecal Coliform

Bacteria are microscopic single cell organisms. Normally, an adult human excretes between 100 billion and 100 trillion such bacteria each day. There are many kinds of bacteria and most serve a useful purpose. Several, however, are pathogenic and are responsible for such diseases as typhoid, cholera, dysentery, polio and infectious hepatitis.

In the wastewater treatment process it is important to kill these harmful bacteria (disinfect) prior to discharging to the receiving stream. The only way to know if the disinfection process has been effective is to analyze the effluent for the presence of these bacteria. Since it would be impractical to analyze for every type of pathogenic organism, the fecal coliform bacteria serves as an indicator organism for all pathogens. Fecal coliform refers to a group of bacteria found in the intestines of animals, including humans, and their presence indicates the potential for the presence of pathogens.

There are basically two accepted methods for analyzing for fecal coliform bacteria. The most probable number (MPN) or Multiple Tube Fermentation method and the Membrane Filter (MF) method. For years, the MPN method was the only method used. This method has many disadvantages. It requires a large number of tubes and a large amount of incubator and water-bath space to hold them. It has several steps and culture transfers and uses complex charts to determine the number of bacteria present. Further, it takes a minimum of 48 hours to obtain results. For these reasons, the MF technique is the preferred method in most wastewater facilities in Mississippi.

The Membrane Filter technique is a fast, simple, economical way to analyze for fecal coliform. It simply involves using a 0.45 micron membrane filter to filter out the bacteria. Since bacteria range in size from 0.5 to 50 microns, any bacteria present will remain on the surface of the filter. Once filtered, the bacteria must be grown or cultured so that they can be seen with low level magnification. The final result is a small blue colony on the filter surface. Extreme care must be taken to avoid contamination from toxic chemicals or other bacteria. To prevent contamination, all glassware that comes into contact with the sample must be sterile. The temperature and the incubation are probably the most important factors in this analysis. Fecal coliform is the only organism that will produce the characteristic "blue colonies" when incubated at 44.5˚C at 100% humidity.

At least three (3) dilutions should be used in the Membrane Filter analysis to ensure a count of between 20 and 60 (ideal count) blue colonies. Any counts outside of this range should not be used in the fecal coliform calculation. The following formula should be used to calculate fecal coliform using the Membrane Filter method:

$$\text{Fecal Coliform (colonies/100ml)} = \text{Colony Count} \times \frac{100}{\text{ml sample}}$$

If none of the dilutions have a colony count that falls within the ideal range, the sample volumes should be adjusted to achieve the desired counts. However, the following procedures should be used to calculate the results when none of the dilutions are within the ideal count range.

1. TNTC (>60): Use 60 as the colony count and the lowest sample volume in the calculation. Record as > result.
2. Less than 20 (<20): Use the colony count (and sample volume) that is closest to a count of 20 in the calculation. Record as estimated count (EC).
3. No growth (0 count): Use 1 as the colony count and the highest sample volume in the calculation. Record as < result.

Sample collection is another critical factor in obtaining accurate results from the fecal coliform analysis. Sample containers must be sterile and pre-treated with a sodium thiosulfate dechlorinating agent. Recently, it has become popular to use the sterile, disposable plastic containers that contain a sodium thiosulfate tablet for collecting samples. This eliminates the need to thoroughly wash, autoclave and pre-treat reusable sample containers.

Grab samples should be collected by hand, in the sterile container, from the effluent after disinfection. Care should be taken to avoid any surface scum accumulations. Samples must be analyzed within 6 hours after collection and should be kept chilled at 4˚C unless analyzed immediately.

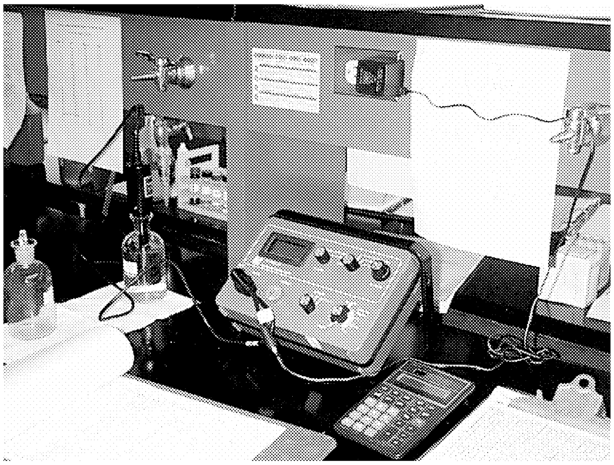
14-9 SUMMARY

As stated earlier, the information provided in this chapter is not intended to serve as detailed instructions for conducting wastewater laboratory analyses. Rather, it is intended to familiarize operators with the laboratory and provide some basic knowledge of the analyses typically required.

More detailed information concerning the specific analyses discussed in this chapter is available from the Mississippi Department of Environmental Quality Laboratory.

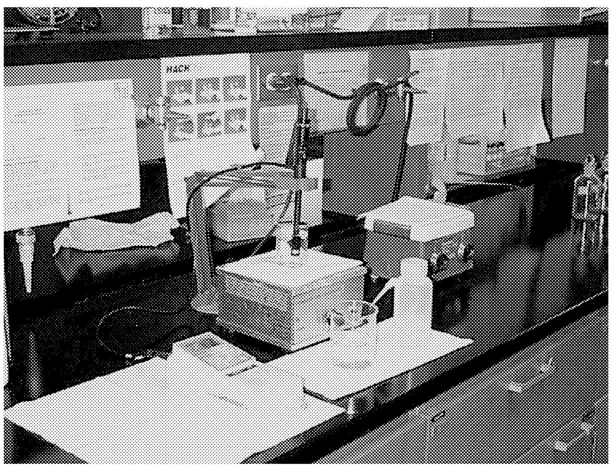
EXHIBIT 14-2

CLEAN WELL ORGANIZED LAB

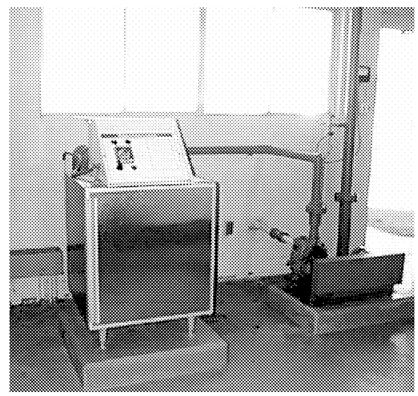


Dissolved Oxygen Meter

Analytical Balance



pH Meter



Refrigerated Automatic Sampler

Autoclaves for Sterilization

EXHIBIT 14.3

TYPICAL WASTEWATER LABORATORY EQUIPMENT

CHAPTER 15

FACILITIES MANAGEMENT

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CHAPTER 15

FACILITIES MANAGEMENT

15-1 BASIC PRINCIPLES

Wastewater treatment facilities usually represent significant investments of money, time, and people. These investments, plus the regulatory requirements which dictate certain levels of performance for protection of the environment, demand that the facilities be effectively managed. Improper management of a facility typically results in such liabilities as excessive costs or other economic hardships, lawsuits, or environmental damages. Thus, effective management must be considered a vital and fundamental need that must be met at each facility.

What is management? What does a good manager do? Answers to these questions are not necessarily the same for all situations. A manager's tasks can vary from industry to industry as well as from facility to facility within the field of wastewater treatment. However, there are certain basic principles which most would agree are applicable to being a good manager in any endeavor and which define the general concepts of effective management.

According to the dictionary, management can be defined as the use of sound judgment to accomplish an objective. Other sources define it as the act of controlling and directing people and resources to effectively accomplish a stated mission. Still others describe it as the art of working with people to make good things happen. More comprehensively, it generally involves the use of available resources in an efficient manner to achieve a predetermined goal. Regardless of one's preferred definition of management, most people would agree that a good manager should be capable of:

1. Dealing effectively with all kinds of people, both those under his or her direction and those not so;
2. Motivating people under his or her direction to work together to achieve a common goal;
3. Effectively communicating instructions, procedures, and expectations to everyone affected by his or her efforts;
4. Accurately evaluating the quantity and quality of resources at his or her disposal, and wisely using these resources;
5. Devising and administering plans with vision and direction;
6. Organizing and delegating responsibilities among persons under his or her direction; and
7. Firmly, but fairly, controlling the activities of persons under his or her direction to ensure that objectives are accomplished.

The aforementioned definitions and characteristics of good managers are intended to describe the basic responsibilities of management, regardless of the type or size of the organization being managed. With specific regard to wastewater treatment facilities, a manager usually has responsibilities which in some way address the following topics:

1. Personnel,
2. Planning,
3. Regulations,

4. Finances,
5. Operation and Maintenance,
6. Safety and Health,
7. Emergency Preparedness and Response, and
8. Public Relations.

Discussions of the role of a good manager in addressing each of these responsibilities follow.

15-2 PERSONNEL

a. General

People are the heart and soul of any organization. The performance of any organization reflects the people which comprise that organization. Thus, having competent and qualified personnel in sufficient numbers is absolutely essential if a wastewater treatment facility is to be properly operated and maintained. It does not matter that a facility may be well-designed and properly-constructed if there are not enough competent and qualified people available to operate the processes and maintain the equipment. Because of this, one of the most important responsibilities of a good manager is to make certain that his or her facility is properly staffed.

With this in mind, it is the manager's responsibility to:

1. Seek and find competent and qualified people to fill staff positions;
2. Provide adequate training opportunities for personnel to develop and improve their abilities to perform their jobs;
3. Motivate personnel to consistently perform to the best of their abilities to help achieve the objectives of the facility;
4. Evaluate performances of personnel individually and the facility as a whole; and
5. Administer a personnel policy which addresses such matters as organizational structure, job descriptions, benefits, promotions, compensation, records, disciplinary action, attendance/ absenteeism, tardiness, and similar matters which govern and affect day to day job performance.

b. Hiring Employees

Anytime a job opening occurs, a good manager will do everything within his or her authority to fill the position with a competent and qualified person. The filling of such positions begins with a genuine effort to **seek and find** the right person. It is the manager's responsibility to actively recruit applicants that meet the requirements of the position.

The first step in recruitment is to "get the word out" that a job opening exists. This can be achieved in a number of ways that include, but are not limited to, the following:

1. Advertising in the classified section of local and/or statewide newspapers;
2. Advertising in journals and newsletters of wastewater organizations;
3. Seeking referrals from employees, technical schools, associations, and other managers; and
4. Maintaining and referring to the files of previous applicants.

Regardless of the methods used in "getting the word out" when recruiting personnel, a good manager should clearly define the vacant position in terms of a job description, work hours, minimum education and experience requirements, opportunities for training and advancement, salary range, benefits available, a description of the selection process, and the name/address/telephone number of a person to contact about the position. In citing education or experience requirements, only those qualifications which will actually be used in the selection process should be noted.

Once the initial process produces names of persons interested in the position, a manager's next action is to begin the actual selection process. The process should begin with having each person complete a standard application form that asks for such things as name, address, telephone number, Social Security number, brief work history, education, references, and such other specific information as the position may justify. In addition, depending on the position, the application form may be supplemented with a request for a full resume` on the person.

Once all the applications have been received, a good manager will take the time to read and evaluate each of them. As information on each applicant is thus reviewed, questions should be compiled that might need to be asked later during an interview. Using the review of the applications as a basis, interviews should thence be scheduled with those applicants whose information best seems to match the job.

Interviews can be misleading, but they can also be very enlightening. The most effective interview process is usually the most organized process. With this in mind, it is good management practice for an interview process to include, but not be limited to, the following:

1. The interviewer should have a copy of the applicant's completed application form (and resume` if required) and the job description in hand at the time of the interview.
2. A relaxed and friendly tone should be established by the interviewer when greeting the applicant.
3. A site that is confidential and without distractions should be used.
4. Adequate, but not excessive, time should be allowed.
5. All questions asked by the applicant should be answered.
6. The interviewer should be well-schooled in legal "do's and don'ts" to prevent potential problems after the interview.
7. At the end of the interview, the interviewer should describe what happens next in the process.

Following the interview process, a good manager will review the information and impressions gathered in talking to the applicants and then follow up with reference checks on those who seem to best match the job requirements. Second interviews may be needed to clarify certain points or to discuss certain matters in more depth. In any event, after evaluation of all the information at his or her disposal concerning the applicants, the manager must ultimately make a decision as to which is the best person for the job. But, by using deliberate recruitment procedures, he or she is better prepared to make a wise decision than if such procedures were not followed.

Actively recruiting competent and qualified personnel obviously requires more effort and time than not doing so; but the chances of finding the best person to fill the position are greatly improved. An effective manager will always seek competent and qualified applicants from which to hire someone. Such action must be undertaken with seriousness and fairness. The final act of selecting an individual to fill a position should be the result of interviews with the applicant, inquiries of references, and a thorough evaluation of all information compiled on the individual. Hiring someone simply to have the position filled should be avoided; instead hiring someone should be the result of an active recruitment process.

c. Training

Effective management includes providing ample training opportunities for personnel. Concisely stated, training simply allows an individual to better perform his or her job. More specifically with respect to wastewater treatment personnel, proper training offers benefits that include the following:

1. More efficient operation and maintenance practices;
2. Protection of the monetary investment required in constructing the treatment facility;
3. Promotion of a better self-image among employees;
4. Enhancement of the public's image of the treatment facility;
5. Use of better techniques to prevent damage to equipment, to troubleshoot processes, and to make meaningful adjustments to treatment processes at minimal costs;
6. Reduction of the chances of excessive costs of operation and maintenance, lawsuits, and environmental damage; and
7. Improved retention of employees.

A training program is desirable for each employee. The type, level, and frequency of training offered can be varied in accordance with the job responsibilities; but no position, regardless of how low or how high it may fall within the organizational structure, should exist without training opportunities.

There are various types of training that a manager can make available to personnel. The type that is most effective depends on the needs of the facility and opportunities that are available within budgetary constraints. Examples of training that a manager might consider in developing training programs include the following:

1. Formal/Classroom Approach — This type of training consists of short courses, college extension classes, seminars, workshops, invited speakers, special classes offered by industry associations, etc. The primary advantages of this type training are that is often less time consuming and more material can be covered quickly. The primary disadvantages are that opportunities for misunderstanding exist and information often cannot be tailored to individual needs.
2. Correspondence Courses — This type training has the advantage of allowing the individual to pace himself or herself while testing the course material on the job. A disadvantage is that it is a self-instructed process which depends heavily on the individual's self-motivation abilities.
3. Participation in Professional Associations — This type of training offers a less formal approach to education, but often is very effective. It includes such activities as attending dinner meetings, trade shows, annual business meetings, and special programs; all of which offer the opportunity to ask questions and exchange ideas with personnel from other facilities.
4. Visits to Other Facilities — These types of opportunities allow personnel to learn by seeing how other facilities operate, observing different types of equipment, and generally learning methods of doing things that may be different from their own.
5. On-the-Job Training — Such activities as cross training to learn other jobs, special assignments, rotation of job assignments, observing and participating in meetings, arranging for a team assignment to solve a specific problem, or assigning older/more experienced personnel to serve as mentors to younger/less experienced personnel can usually be included in day to day activities.
6. Vendor Demonstrations — Inviting vendors to provide demonstrations of new equipment or techniques can usually be achieved easily and can provide very useful information.
7. Miscellaneous In-House Training — This category consists of such efforts as routing trade publications and newsletters to all appropriate employees, making computer internet services available, talks or demonstrations by staff members, or providing books, videos, or other materials as may be requested by employees or recommended by training schools.

In addition to providing the actual training opportunities for personnel, a good manager can do other things to supplement the training and to enhance an individual's willingness to be trained. One such example is to provide an in-house library containing such materials as text books, training manuals, operation/maintenance manuals, manufacturer's catalogs, technical journals, and association newsletters. The library should be in a suitable location with reading/studying areas available. Another example is to keep records on the training completed by each employee and to systematically plan for on-going training with each employee. Providing some type of recognition when an employee successfully completes a particular training effort is also encouraged.

A management system that requires and provides training for employees will not only produce more effective job performances; but it will convey to the employees a sense that the employer cares about the individual's development and overall well-being. An organization that requires and provides training opportunities usually is one in which the employees feel good about themselves and about being a part of the organization. Simply stated, there is every reason to require and provide training opportunities; there is virtually no reason to not do so.

d. Employee Motivation and Morale

One of the keys to successfully managing people is to be aware of individual needs for job satisfaction and then be able to use such awareness to motivate people and enhance their morale. A good manager will make it his or her duty to constantly be alert to those things which affect people in positive or negative ways; and thence act to improve the positive and reduce the negative. Such alertness usually does not happen by chance; instead it requires conscious acts of observing actions and conditions, seeking answers and input, and trying to understand what enhances morale and what weakens morale. A good manager will constantly strive to learn of those things which serve to motivate and inspire people under his or her direction.

As a manager seeks awareness and understanding of those things which influence morale, the task becomes one of applying his or her knowledge to create a work environment that motivates people. In creating such an environment, the following are fundamental needs that most employees consider important and that every manager should address:

1. Interesting Work — The tasks that each employee must perform in his or her job should be interesting, to some extent, to that individual. Obviously, some jobs are more interesting than others; but each job has its purpose, and the person doing the job should at least understand that purpose. Lack of interest in one's work often is the result of simply not knowing why the work has to be done. It is vital that each person know the purpose of his or her job and how it is important to the achievement of the overall goals and success of the facility. Often, people do not exhibit any interest in their job because they do not understand "why" their job is important. A good manager will make certain that each employee under his or her direction knows why their job is necessary. Where possible, people should be placed in positions where they demonstrate the most interest. People will generally do their best work when doing something that interests them.

2. Sufficient Information and Equipment — Morale is weakened when employees do not have sufficient information, supplies, materials, or equipment to do their job. It is vital that management always provide employees with adequate information about why a task has to be performed, what results are expected, and any procedures or methods that must be utilized. Similarly, one must have the materials, supplies, and equipment that match the responsibilities of the job.

3. Responsibility and Authority — Any responsibility that is placed on an individual should be matched with the proper authority for that person to do the job. The manager should make both the responsibility and authority known to all affected parties. If a person lacks the proper authority to "get

the job done", it is unreasonable to expect that the person will be happy or that the task will be completed as successfully as it should have been.

4. Adequate Pay and Benefits — Aside from enjoying what they do, most people seek employment for one reason, so they will have an income and benefits on which to live and plan their lives. Most everyone wants a job that pays well and offers attractive benefits; but most people also understand that compensation varies with job responsibilities. The primary cause of pay-related morale problems is a perception or belief among workers that their pay or benefits are less than it should be for their particular position or that someone else in the same position makes more than they do. A good manager will stay abreast of pay rates and benefits available in the industry and will strive to have comparable/competitive programs that are fairly applied to people under his or her direction.

5. Job Security — Morale can quickly deteriorate if an employee senses or hears that his or her job may be eliminated. Job security issues should be dealt with by management in a forthright manner. Leaving people to wonder or speculate about the status of their jobs is unwise. If certain jobs are to be eliminated, those affected should be told. If rumors are circulating, a good manager will dispel them with facts.

6. Rewards — Human nature demands that people who perform their job well be rewarded. Obviously, the first reward is adequate pay; but beyond this, some type of recognition or display of appreciation is very effective in maintaining morale and motivating others. Often a simple expression of thanks and acknowledgement by one's supervisor is a very powerful motivator. If someone does a good job, they should be told so by those in supervisory and management positions.

7. Seeing Results — Every job has a role in achieving the ultimate goal or success of a facility. Many times, however, that final success is not seen by everyone who contributed to its achievement. For example, if a treatment facility achieves compliance with its permit, a good manager will make certain that everyone involved knows it. Conversely, if compliance is not achieved, everyone should know. The sharing of such results promotes the concept of teamwork and creates interest in job performance.

8. Discipline — Every employer has certain rules which its employees are expected to follow. It should be made clear to everyone what the rules are and that there are certain consequences to breaking those rules. Human nature is generally such that people expect and even desire some boundaries (rules) to what they can and cannot do. The key to being a good manager in such matters is to inform people; to make certain that those affected know about the rules and know what disciplinary action will be forthcoming if the rules are violated. Thence, it becomes a matter of consistently and fairly administering the discipline in accordance with the rules.

9. Expectations — One of the simplest and most effective, but often overlooked, principles to apply in motivating people is to make certain they know what is expected of them. A great injustice is done to employees when they do not know exactly what it is they are supposed to do. A good manager will be absolutely certain that employees clearly know and understand what they are expected to do.

10. Opportunities for Advancement — A major motivator, especially among younger or new employees, is having some sense of being able to "move up" in the organization. The extent to which this is possible will vary with the size of the organization. When such opportunities exist, a good manager will make certain that affected employees are aware of them. As with job security issues, opportunities for advancement should be dealt with in a forthright manner. People should know what opportunities exist as well as those that do not exist.

While acknowledging that most employees will view the aforementioned items as being fundamental to having a proper work environment, it should be understood that the underlying factor that will define the motivational efforts of a manager is his or her leadership qualities. With this in mind, a good manager should possess or develop certain leadership characteristics that will enhance his or her abilities to motivate people. These include, but are not limited to, the following:

1. Consistency — An effective leader should be consistent in his or her behavior patterns. Inconsistency in daily behavior will result in confusion and hard feelings.
2. Friendliness — A genuine friendliness and sincere like of people is a trait of good leadership. It is human nature for people to like to have their supervisors act in a friendly and informal manner toward them.
3. Respect for the Individual — People are different. An effective leader will respect traits and beliefs of individuals. In order to influence people, a leader must recognize their differences and deal with them accordingly.
4. Truthfulness — When asked a question, a good leader will give an individual a straight answer or refuse to comment if he cannot give such an answer. He does not manipulate or "twist" the truth. A person wants to feel like he or she can believe and trust their supervisors.
5. Promptness — Procrastination breeds ineffectiveness. A good leader will be prompt in administering policy.
6. A Good Listener — A leader knows the importance of being alert and concentrating when someone is speaking to him or her.
7. Loyalty — Exhibiting strong support for and loyalty to his or her staff is a characteristic of a strong leader.
8. Team Player — A competent leader knows that cooperation and teamwork are essential for success.
9. Innovator — In this age, being receptive to new ideas and being willing to try new things is essential to effective leadership.
10. Recognize/Acknowledge Others — A leader is quick to recognize the efforts of others and provides proper acknowledgement of jobs well done.
11. Firmness — When the occasion arises, a leader is willing to stand firm on an issue, even when such a stand is unpopular.
12. Objective — An effective leader always makes an effort to be objective and minimize bias in dealing with people.

Motivating people and maintaining high morale cannot be achieved by occasional acts of good will. Instead, it requires a commitment to continuously being attentive to those things that influence people's attitudes and feelings.

e. Performance Evaluation

Both employer and employee have a right and need to know if a job is being performed satisfactorily. A manager should have a fair and consistent system of evaluating the performances of all personnel under his or her direction. Such a system should include recognition of successful performances and identification of poor performances. Information compiled in such evaluations should be used by the manager in planning for future needs as well as for addressing current improvements.

In general, an effective process for evaluating employee performance should involve the following components:

1. Establish goals for each employee;
2. Formulate plans for achieving goals;
3. Take action to achieve goals; and
4. Evaluate action taken.

Once the process begins, it becomes cyclic with each evaluation marking the beginning of a new cycle.

Once a process has been developed based on the aforementioned components, the process can be implemented in certain ways that will enhance the chances of it working effectively. Some of the things that can be done to help make the process meaningful and useful include:

1. Two-Way Exchange — The process should be a two-way exchange in which the evaluating supervisor and the person being evaluated are partners. Both should be able to exchange thoughts about the strengths and weaknesses of the other as they relate to job performance. These exchanges must take place in an atmosphere that is not adversarial.
2. Frequency — As a general rule, new employees should be evaluated at the end of a designated trial period. After that, annual evaluations are usually thought to be adequate.
3. Records — A record should be kept of each evaluation and the employee should be provided with a copy thereof. The format of the record should be as simple and uncluttered as practical.

As with any system involving personnel, an evaluation process must be based on integrity if it is to achieve its purpose. Giving "lip service" to the process and thence not really using the information gained therefrom creates distrust among employees toward the employer. The process must be implemented in a manner that encourages an honest exchange between the person doing the evaluation and the person being evaluated.

f. Personnel Policy

Regardless of the size of a facility, it is good management practice to have written policies which address common personnel matters. While such policies may need to be periodically reviewed and revised, having them in place to follow can simplify issues and enhance fairness in dealing with personnel matters. The content of a personnel policy can and should vary to match the size and type of organization. As a general rule, however, any policy should, as a minimum, address the following matters:

1. Organizational Structure — A breakdown of the "chain of command" which depicts the accountability structure of the organization in chart form should be available for all employees.
2. Job Descriptions — A written description of each personnel position should be kept on file and should be dispensed to each employee when he or she is hired.
3. Benefits — A brochure or other written format should be used to describe the benefits package that is available to each employee. Said information should be given to new employees. At such time that changes are made in the package, new information should be dispensed to all employees.
4. Promotions — A written policy governing the organizations procedures for employee promotions should be on file and available to any employee at any time.
5. Compensation — Without revealing individual salaries or pay rates, rate schedules or salary ranges which depict the pay for various positions should be maintained on file and updated as needed. Such information will allow employees who aspire to move into other positions to know what compensation could be anticipated.
6. Records — A "personnel" file should be maintained on each employee. Access to this file should be limited to the employee, his or her supervisor, and other persons as may be authorized by the organization.
7. Disciplinary Action — A written policy on the procedures which are to be followed when a disciplinary matter is to be addressed should be on file. Said policy should be given to all new employees and existing employees who may be subject to any such action.
8. Attendance/Absenteeism/Tardiness - A written policy governing the expectations of employees with regard to attendance, absenteeism, and tardiness should be given to all new employees. Included in this policy should be the consequences of non-compliance.

Depending on the preference of the organization, a written personnel policy addressing the aforementioned items and others that may be appropriate can be achieved with individual documents for each matter or in an "employee handbook" which addresses all matters. The format is not so important. What is important is to have written policy governing the various matters. As a management tool, such policies are invaluable in dealing consistently and fairly with people.

15-3 PLANNING

It would not be wise to begin a long journey without having a map to serve as a guide in selecting routes that would best meet needs. Such is the role of planning in managing a wastewater treatment facility or other entity. A plan serves as a guide in helping make pertinent decisions about the "route" the facility is to follow during its useful life. In formulating a plan for a facility, one should understand two things. First, planning is an on-going process; it does not end with the preparation of a document called a plan. A plan should be subject to continuous review and revision as needed. Secondly, a plan is not some rigid law that must be followed no matter what the consequences; instead it is a guide that can and must have flexibility.

Planning is an integral part of management, particularly from the perspective of developing and administering a budget. Without a planning process, it can be argued that true management of people and resources is not possible. Good management requires a certain amount of foresight or trying to develop expectations about future needs, which in essence is what planning is about. To manage a facility properly, not only is it necessary to meet existing needs; it is also essential to have some idea of what needs and resulting costs will be forthcoming. Projecting future needs is the planning process in a nutshell; and, while not an exact science, it can be achieved with sufficient thought and experience to the point where it will be a very useful management tool. Without it, a facility and its personnel have no sense of long-term direction.

The planning process should address a number of needs, which may vary depending on the size and type of facility. As a general guide, however, planning for the management of a wastewater treatment facility should, at least, address the following:

1. <u>Operation and Maintenance</u> — Operation and maintenance needs (both corrective and preventive) are constant, but yet they vary. Planning should involve such budgetary needs as known equipment servicing, repairs and replacement, materials, supplies, and other special items related to operation and maintenance.
2. <u>Capital Improvements</u> — When major improvements are needed such as a new pumping station or even a new treatment facility, the expense is usually very significant. Under most circumstances, the need for this type of major improvements can be seen well ahead of time; and, consequently, can be planned for in a timely manner.
3. <u>Staffing/Personnel</u> — A good manager will have a "staffing plan" that will encompass virtually all personnel needs. Such items as salary adjustments, benefits, filling and/or eliminating certain positions, etc. should be planned for and included in the preparation of a budget.
4. <u>Training</u> — Because training is important to having a competent and qualified staff, specific events, materials, and supplies should be planned for and included in the preparation of a budget.
5. <u>Materials/Supplies</u> — The numerous materials and supplies that are needed to properly operate, maintain, and manage a wastewater treatment facility should be included in the preparation of a budget. Adequate allowances should be made for such things as chemicals, lubricants, office supplies, office furniture and equipment, etc.

6. Utilities — A wastewater treatment facility must have water, electricity, gas, and telephone in order to function. These items can be predicted, usually within reasonable accuracy.
7. Vehicles — Just as utilities are necessary in the operation of a treatment facility, so are vehicles. Each year, plans should be made as to the anticipated expense of servicing and routine maintenance as well as whether to repair or replace certain vehicles.

Planning can be made a lot easier if there are good records on which to review past performances and expenses. Projecting future needs on the basis of past performances and expenses is usually a reliable planning method if the records are thorough and accurate. An effective manager will maintain good records on all facets of his or her operation. Records should be kept on such things as facility performance, equipment maintenance, personnel matters, costs of all kinds, accidents, inspections, visits, training, unusual events, weather, etc.

15-4 REGULATIONS

a. General

Virtually every aspect of life today is affected to some extent by governmental regulations. Wastewater treatment facilities certainly are no exception. Each facility is subject to the requirements and conditions of permits which regulate the quality of its effluent, its sludge disposal practices, and the qualifications of its operators. In addition, there are regulations which influence employment practices, safety of employees, and building requirements. Still further, there are regulations which govern financial matters and funding of capital improvements. The manager of a wastewater treatment facility must know which regulations affect his operation, what the facility's obligations are for compliance, and what penalties exist for non-compliance.

Regardless of the type of regulations a manager must be concerned with, he or she has to eventually deal with a person who represents the regulatory agency. It is to the considerable advantage of the manager to develop a friendly working relationship with the regulatory agency. An adversarial relationship should be avoided. This is not to say that a manager should not express his or her opinion or seek answers to difficult questions. The exchange of ideas, opinions, and information should be open and honest, but it should always be achieved with a courteous and cooperative attitude.

A manager must stay abreast of local, state, and national environmental regulations which affect his or her facility. He or she must establish the name, address, and telephone number of a contact person with each agency that has jurisdiction over his or her facility. When regulatory problems occur, as they will eventually, the manager must inform the appropriate agency in a prompt and forthright manner. Above all, a good manager will maintain a cooperative and courteous attitude in dealing with the agency.

b. Environmental Regulations

Probably most, if not all, wastewater treatment facilities exist because of regulatory requirements. Said requirements are in effect for one reason, which is to protect the environment from water pollution. The two (2) most obvious environmental regulations with which the manager of a wastewater treatment facility must be familiar are those which relate to National Pollutant Discharge Elimination System (NPDES) permits for effluent discharge and those which relate to sludge disposal, commonly referred to as "503 Regulations." It is important that a manager be very informed on the conditions and requirements of the permit(s) assigned to his or her facility. In addition, there may be other environmental regulations from time to time that demand a manager's attention. Such could include those which govern underground storage tanks, hazardous materials, and air emissions. One local regulation with which familiarity is needed by a manager is the sewer use ordinance which governs the quality and quantity of materials which can be placed in the area sanitary sewer system.

c. Employment Regulations

In today's regulated world there are numerous regulations, most of which are national in origin, which affect employment practices. The wastewater treatment facility manager is no different from any other manager who has people under his or her direction. He or she simply must know, understand, and comply with the regulations which affect employment. Failure to do so can lead to legal problems and liabilities that are very undesirable.

Examples of current regulations with which a good manager will become familiar include those dealing with the following:

1. Fair Labor Standards Act (FLSA) — The major component of this statute is the requirement that employees be paid at least the minimum wage and be paid overtime for working more than 40 hours per week unless exempt. Exempt employees generally consist of persons classified as professional, executive, or administrative.

2. Civil Rights Act of 1964 — Title VII of this act prohibits employment discrimination on the basis of race, color, national origin, religion, and sex for employers with 15 or more employees.

3. Sexual Harassment — Today's regulations governing sexual harassment originated with the Civil Rights Act of 1964. As previously stated, Title VII of that act prohibits employment discrimination on the basis of race, color, national origin, religion, and sex for employers with 15 or more employees. Later court rulings extended sexual harassment protection to all employees, regardless of the number of employees. There are varying definitions of sexual harassment; and the clarification of such is significantly beyond the scope of this manual. However, a good manager will, with appropriate legal advice, establish certain standards of behavior which are deemed to be acceptable in his or her jurisdiction.

4. Americans with Disabilities Act (ADA) of 1990 — Extending from the Rehabilitation Act of 1973 and the Civil Rights Act of 1964, the ADA is intended to eliminate discrimination against disabled individuals in the areas of employment and public access.

5. Occupational Safety and Health Act (OSHA) — OSHA requires employers to furnish a workplace that is free from recognized hazards that cause, or are likely to result in, death or serious physical harm.

6. Age Discrimination in Employment Act (ADEA) of 1967 — ADEA protects all workers 40 years of age and older from age discrimination in recruiting, hiring, compensation, and training.

7. Affirmative Action (AA) — Affirmative action policies require that a certain percentage of government-funded work be set aside for minorities. At the present time, there are numerous debates and court cases involving the constitutionality of affirmative action policies.

8. Labor Unions — Regardless of one's personal feelings toward unions, they have had a significant impact on working conditions, wage rates, and consumer prices in this country. The rights of unions vary from state to state. If a state has a "right to work" law such as is the case in Mississippi, a person may not be denied employment based on whether he or she is or is not a member of a labor union. An employment contract in a state with a "right to work" law can not require an employee or job applicant to be a member of a labor union.

In addition to the aforementioned more common regulations governing employment practices, there are undoubtedly others which are more specialized in the concerns which they address. They cover such areas as confidentiality of records, lie-detection tests, family and medical leave, retirement and unemployment taxation, Social Security, and immigration control. As needs arise, a good manager will become familiar with these and other regulations that in any way can affect employment practices or employees at his or her facility.

d. Financial/Funding Regulations

At one time or another, managers of wastewater treatment facilities usually get involved with the task of obtaining funds for making improvements. Regardless of the source of funding selected, there is typically some regulation which governs the spending of the funds and with which the manager must become familiar. Funding sources which are governed to some extent by regulations include general obligation bonds, revenue bonds, state revolving loans, federal and state grants, and user charges. Each of these types of funding sources are under the jurisdiction of various local, state, or federal regulations. To maximize any benefits which may be available from any of these sources, a good manager will know how the particular regulations can affect his or her facility.

15-5 FINANCES

Good management practice obviously requires that the costs associated with operating and maintaining a wastewater treatment facility do not exceed the revenue which is available. A good manager, however, will stay informed on the sources of revenue that fund his or her budget. Part of the responsibility of being a manager is formulating a budget based on anticipated income. There will likely be occasions when the revenue sources may need to be adjusted to generate additional revenue; and the manager should be in a position to recommend how much of an adjustment is needed.

It is important that a manager be familiar with the various types of revenue sources that are available for funding needs at his or her facility. Revenue sources usually vary depending on the application of the funds generated. For example, capital improvement projects usually are funded from special sources such as a bond issue, loan, or grant; whereas routine operation and maintenance expenses typically depend on user charges. The more common sources of revenue that the manager of a wastewater treatment facility would be expected to know about include:

1. User Charges — Proper management practice as well as federal and state laws demand that the revenues needed to operate a publicly-owned wastewater treatment facility be generated from charges assessed to the users of the sewer system and treatment works. These charges are normally based on the quantity of water consumed by each user. In some cases, surcharges are added for high-strength or high-volume wastes. As costs to operate and maintain a facility increase, user charges need to be adjusted. It is recommended that user charges be reviewed and evaluated annually to decide if adjustments in the rates are needed in order to meet anticipated expenses.

2. Sewer Connection Fees — Most sanitary sewer systems/wastewater treatment facilities have a revenue source from connection or “tap” fees that are charged when new users are connected to the system. Many times these charges can be related directly to the costs of making improvements needed to accommodate the connecting user. Others are charged as a flat or lump sum fee regardless of the details of the connection. The income derived from such fees are usually tied to economic development in the area. When there is a lot of development occurring, the revenue may be significant. However, such revenues typically exist only for a reasonable period of time, after which revenues may drop significantly from such sources.

3. Governmental Grants — On occasion, grants are available through various governmental agencies to help fund the cost of major improvements. Often, when available, these grants pay for a designated percentage of eligible costs. In recent years, the availability of grants has diminished dramatically.

4. General Obligation Bonds — General obligation, or "G.O.", bonds are backed by the full taxing authority of the issuer and are normally used to finance capital improvement projects. Under such authority, the issuer can use ad valorem (property) taxes to repay the bonds. The issuer can also elect to repay the bonds by increasing service charges such as user rates in the case of a sewer system and treatment facility. The credit rating held by a public body influences the interest rate at which the bonds can be sold. Interest rates on general obligation bonds are usually lower because they are backed by the full credit of the community issuing the bonds. The amount of bonds which can be issued by a community is limited by law to a designated percentage of the property valuation in the community. Voter approval is required for the issuance of general obligation bonds.

5. Revenue Bonds — Insofar as wastewater collection and treatment systems are concerned, these bonds are a common and popular source for financing major construction projects. This is especially true for existing systems where an established record of income and expenses exists. Bond payments are made from revenue generated by user charges. Said charges are usually increased with the issuance of the bonds. There are no legal limits on the amount of revenue bonds which can be issued; however excessive issuance can make the bonds risky and therefore unattractive to investors who might purchase the bonds. Revenue bonds do not have to be approved by voters to be issued.

6. Special Assessment Bonds — When only certain properties will benefit by a capital improvement, special assessment bonds can be issued. Such bonds are not payable from taxes. Instead, they are paid by assessing the affected properties. Special assessment bonds are generally considered a higher risk by investors than general obligation bonds because they are not backed by the taxing authority of the community. Subsequently, they usually have higher interest rates.

7. Impact Fees — In an area where growth is significant, impact fees can be charged to developers in exchange for services to their development. For example, if a proposed subdivision desires to be served by an existing sewer/treatment system, a certain percentage of the capacity of the existing facilities would be allotted to the new development. The owner of the existing system would charge an impact fee to the developer as a means of being compensated for the capacity to be allotted. Impact fees are more common in areas where development rates are high. A potential negative effect of impact fees is that they can discourage development if they are levied in an unreasonable manner.

8. Special Taxes — Although not a common occurrence, certain locations may have special taxing authority that can be allocated to capital improvements. For example, where taxes are levied on such items as liquor, tobacco, gaming, or motel/hotel occupancy in a resort area, a certain portion of the funds collected may be allocated to improvements such as a wastewater treatment facility.

Regardless of the sources which may be available to generate revenue for his or her facility, a good manager will regularly monitor their status and evaluate the expectations for the next budget. Being prepared to reasonably project revenue needs is just as important as managing an existing budget. Both are essential components of good management and financial responsibility.

15-6 OPERATION AND MAINTENANCE

Once a wastewater treatment facility is properly designed and constructed, its success or failure is directly dependent on the level of operation and maintenance which is practiced at the facility. It is the responsibility of a good manager to provide the ingredients necessary to have reliable and effective programs for operating and maintaining his or her facility. Such ingredients can vary with the size and type of facility, but certain components or concepts are deemed to be appropriate regardless of the facility. These include:

1. Personnel — The heart and soul of any organization are its people. If an adequate number of competent and qualified people are available to perform operation and maintenance tasks, then a successful program for each can be rightfully expected. Conversely, without an adequate number of competent and qualified people available, successful programs cannot be expected.

2. Organization — Efficiency and effectiveness are usually by-products of a well-organized effort. Without question, operation and maintenance tasks are more efficiently and effectively accomplished if properly organized. A helter-skelter approach to such tasks inevitably leads to problems which otherwise could have been prevented.

3. Planning — Systematic planning is absolutely essential to successful operation and maintenance at a wastewater treatment facility. The technical nature of the tasks and regulatory demands for efficient performance require managers to use planning as an on-going and essential tool.

4. Training — Because operation/maintenance techniques and regulatory requirements are subject to constant change, the competency and qualifications of personnel involved in such tasks must also change. Training of personnel is a major means through which competency is increased, qualifications are enhanced, and performance is improved.

5. Preventive Maintenance — As anyone associated with equipment maintenance can attest, it is virtually always more cost effective and time efficient to practice preventive maintenance as opposed to corrective maintenance. Preventive maintenance schedules and records should be a rigid requirement of any maintenance program. A good manager will make certain that such a program is in place and is followed religiously.

6. Records — Records of any maintenance activity should be maintained accurately. Such records should be used in reviewing past budgets and formulating new budgets.

7. Parts/Tools/Materials Inventory — Obviously, the number and type of spare parts, tools, and materials that a facility keeps on hand will vary depending on the size, type, and location of the facility. However, regardless of the magnitude of parts, tools, and materials which need to be kept on hand, a workable inventory system should be practiced. A good manager will know how many of which parts need to be on hand, how many are actually on hand at any time, how many need to be ordered, and where the parts have been used. The same concept applies to tools and materials used in the operation and maintenance tasks. A manager should know what is needed, what is on hand, and where things have been used.

8. Budgetary Controls — A manager needs some type of system to assist in controlling expenditures and staying within budgetary constraints. Many managers utilize some system of purchase orders or similar pre-purchase record to monitor and control expenditures. Whatever the details of the records, it is good management practice to have a system defined by required procedures for expenditures to be made.

9. Professional Support — Operation and maintenance responsibilities are such that outside professional help is frequently needed to resolve certain problems. A good manager will have prior arrangements made with his or her superiors that will allow him or her access to an engineer, attorney, accountant, or other professional when the need arises. It is wise for such access to be a budgeted item.

10. Computerized Data System — Computers have entered virtually every area of people's lives. Wastewater treatment facilities are no exception. Many facilities already utilize computers to store laboratory data, complete discharge monitoring reports, monitor maintenance schedules, and expedite many other tasks. While not a necessity, it is a fact that, properly applied, computers can be used to allow management, operational, and maintenance personnel to be more efficient. There are numerous software packages available that can assist with maintenance management and operational tasks. As costs continue to decrease, the use of computer applications will become common practice.

15-7 SAFETY AND HEALTH

It is a fundamental obligation of management to provide and maintain a safe and healthy workplace. Failure to do so will inevitably yield such undesirable results as injuries, illness, lawsuits, reduced productivity, low morale, and financial liabilities. Supervisory personnel can be held liable for unsafe actions or conditions that exist in the workplace. As a minimum, those responsible for managing a wastewater treatment facility should make certain that the following provisions are made:

1. Safety Program — A formal and effective safety program should be in place and should be implemented with seriousness. A designated individual or individuals should be in charge of the program and should be held accountable for dispensing appropriate material and instructions.

2. Equipment and Tools — It is difficult for safety to be practiced without proper tools and equipment. A manager should keep the proper tools and equipment in place for employees' easy and convenient use.

3. Training — As with any task, people need to be properly trained if they are to be expected to perform properly. Safety is too important to not provide adequate training. On-going training opportunities should be made available and employees should be required to participate.

4. Material Safety Data Sheets — Safety data sheets should be available for all materials which employees must handle or come in contact with.

5. Safety Handbook or Other Written Policy — A written safety policy should be available and employees should be required to be familiar with it. Said policy should include the posting of appropriate safety signs and rules, procedures for accident reporting and analysis, and procedures/penalties for violation of safety rules.

6. First Aid and Emergency Procedures — First aid stations and procedures for emergency responses should be sufficiently placed; and employees should be required to demonstrate their knowledge and understanding of the proper use of such.

One of the most effective things that a manager can do to create an attitude that safety is important is to set an example with his or her own behavior. Leadership by example will go a long way toward gaining employee support and belief in maintaining a safe and healthy work environment.

15-8 EMERGENCY PREPAREDNESS AND RESPONSE

Contingency Planning

Most any wastewater treatment facility is subjected to emergency operating conditions from time to time. Said conditions can be the result of a disaster or emergency resulting from one of the following categories of events:

1. Natural Causes – Such events are normally weather-related and include such things as tornadoes, floods, ice, snow, etc.

2. Human or Technological Causes – These types of events are the result of some human-induced act and include such things as dam failures, fires, riots, hazardous material spillage, energy shortage, materials shortage, etc.

3. National Security – Such events would include an attack by a foreign power or an act of terrorism.

A responsible and effective manager will evaluate his or her facility for vulnerability to emergencies and disasters in each of these categories and formulate a contingency plan for appropriate responses.

In formulating contingency plans for responding to emergencies and disasters, it may be useful to understand terminology as normally used by federal and state emergency response agencies in defining such events. Emergencies are generally categorized as those events which may have devastating effects but which can ordinarily be handled with local resources. An emergency may occur during and after a disaster. Disasters, on the other hand, generally are considered to be events which require resources beyond local capabilities; and more often than not, are weather-related.

When analyzing the vulnerability of a facility to certain types of emergencies or disasters, a suggested point of beginning is to assign a Risk/Hazard Assessment Rating which rates the probability of occurrence on a scale of 0 to 4 as follows:

Risk/Hazard Assessment Rating	Probability of Occurrence
0	Very Unlikely
1	Not Likely, But Could Occur
2	Likely
3	Very Likely (Has Occurred More than Once within Past 10 Years)
4	Probable

A contingency plan is generally recommended for any emergency or disaster which is considered to have a Risk/Hazard Assessment Rating of 2, 3, or 4. For each event with such a rating, an assessment of the vulnerability of the potential hazards associated with the event should be made. Such an assessment simply involves a listing of the potential problems that could result from the occurrence of the event. For example, if the event were a tornado, potential problems might include building or structure damage, power outage, spills, by-passes, transportation problems, or communication problems. Once the vulnerabilities or potential problems are thus assessed, the results should be the basis for formulating a contingency plan for responding to each.

There are four (4) basic phases of emergency/disaster preparedness which a good manager will address in the preparation of any contingency plan. These phases are:

1. Mitigation – This includes actions taken prior to a disaster or emergency that are aimed at reducing the probability of occurrence or that will reduce the effects thereof. An example is training of personnel for emergency operations.

2. Preparedness – Preparedness is simply good insurance. It greatly increases the chances that the most effective and most efficient responses will be enacted when the time comes for such action. Examples include stockpiling materials and supplies and executing mutual-aid agreements with others to share resources.

3. Response – This phase involves those activities which take place during and after a disaster or emergency. Examples of such activities may include responses to spills or by-passes, remedial actions to continue or resume operations of equipment, inspection of all components of a system affected by the event, documentation of damages and expenses, and use of the media to disseminate information.

4. Recovery – This phase involves those activities which are implemented to return to normal operations. Such activities may include clean-up, repair/replacement of damaged equipment, seeking of financial assistance as may be available, and re-evaluation of the mitigation phase.

The depth and detail addressed by each of these phases of contingency planning will vary for each facility depending on the type facility, its location, and the vulnerability assessment for each disaster or emergency. Whatever the depth and detail required, the critical concern is whether such planning exists. Good management demands that it does.

Incident Response

Following the events of September 11, 2001, President George W. Bush signed Homeland Security Presidential Directive-5 (HSPD-5, February 28, 2003) mandating that all government entities (local, State and Federal) adopt the National Incident Management System (NIMS). NIMS provides a nationwide template for all government, private sector and non-governmental agencies to work together during response to domestic incidents. This includes public works agencies responsible for ensuring an effective response to incidents involving critical infrastructure such as water and wastewater facilities.

NIMS is comprised of several components that work together as a system to provide a national framework for preventing, preparing for, responding to and recovering from domestic incidents. These components include:

1. Command and Control
2. Preparedness
3. Resource Management
4. Communications and Information Management
5. Supporting Technologies and,
6. Ongoing Management and Maintenance

NIMS incident command and management structures are based on three key organizational systems:

1. The Incident Command System (ICS), which defines the incident command and management components and organizational structures throughout the life cycle of the incident. ICS is a proven all hazard incident management system applicable across all agencies and jurisdictions.

2. The Multiagency Coordination System which defines the management components and organizational structures of supporting entities.

3. Public Information Systems, which include the processes, procedures and systems for communicating timely and accurate information to the public during emergency situations.

Preparedness includes planning, training, exercises, personnel and equipment certification standards, mutual aid agreements and Emergency Management Assistance Compacts (EMACS).

NIMS defines standardized mechanisms and establishes requirements for inventorying, mobilizing, dispatching, tracking and recovering resources over the life cycle of an incident.

Incident management organizations must ensure that effective, interoperable communications hardware, processes, procedures and systems exist across all agencies and jurisdictions involved in an incident.
Supporting technologies include voice and data communications, information management systems for record keeping and resource tracking and data display systems.

The Department of Homeland Security, established the NIMS Integration Center to provide strategic direction, oversight and ongoing management and maintenance of NIMS over the long term. Managers and operators should receive NIMS and ICS training to enable them to function effectively within these systems during response to emergency or disaster events involving their facilities. The training is available online at www.training.fema.gov and through the Mississippi Department of Homeland Security and Mississippi Department of Environmental Quality.

Site Security

Site security has always been a major concern for wastewater facility managers. It is even more important in the wake of recent acts of terrorism in this country. The U.S. Department of Homeland Security and United States Environmental Protection Agency have identified wastewater facilities as critical infrastructure. These agencies have issued guidelines for protecting these critical assets.

Tools have been developed to assist managers in assessing security vulnerabilities and in implementing corrective actions. One such tool is “Protecting Your Community’s Assets: A Guide for Small Wastewater Systems” developed by the National Environmental Training Center at West Virginia University (www.netcsc.wvu.edu). Another computer based software tool developed, primarily, for larger wastewater systems by the Association of Metropolitan Sewerage Agencies is “Vulnerability Self Assessment Tool”(VSAT) (www.vsatusers.net). Both of these tools are available to managers on their respective websites.

Recommended security measures for wastewater facilities include:

- Keep perimeter outside fences clear of vegetation
- Keep gates and chemical storage areas locked
- Install motion/light sensor lighting
- Keep all doors and windows locked
- Consider 24 hour staffing
- Police patrols
- Install surveillance cameras and alarm systems
- Neighborhood Watch Program
- Access security
- IT/Computer security

Managers and operators should immediately implement site security measures to protect their critical assets. For assistance in conducting vulnerability assessments, contact the Mississippi Department of Environmental Quality.

15-9 PUBLIC RELATIONS

A wastewater treatment facility’s reason for existence is to protect the environment from water pollution. Such protection is a service to the “public”; hence, each facility has an automatic relationship with the public. It is a manager’s responsibility to develop and maintain good public relations on behalf of his or her facility. The underlying principle on which good public relations should be based is to first do a good job in operating and maintaining a facility and then let the public know about it. No amount of publicity can hide a poor operation. On the other hand, a good operation that is unknown will generate no support from the public it serves. Thus, it is important that both a good job be done and that the public be made aware of it.

The manager should assume the lead role in developing and maintaining good public relations. However, a good manager will convey to all employees under his or her direction that everyone is expected to promote good public relations. Such fundamentals as good conduct, proper appearance, friendliness, courtesy, and helpfulness should be demonstrated toward the public at all times.

There are various aspects of developing and maintaining effective public relations that a good manager will be certain to address. These include such things as:

1. Routine Public Contacts — Regardless of their position in the chain of command, every employee of a wastewater treatment facility should understand and remember that they work for the "public". Consequently, every contact with a member of the public is an opportunity to enhance good relations. Whether it is a concerned citizen calling to report a problem or a disgruntled sewer customer complaining about a bill, a certain code of conduct should be practiced. When engaged in a conversation with the public, one should always strive to be courteous and responsive. A manager should make certain that people who routinely deal with the public via telephone or in person have personalities suited for such tasks. When working on problems which affect specific individuals, a good manager will keep said individuals informed as to schedules and the status of the work. When correspondence is needed in communicating with the public, care should be taken to use wording that is friendly, clear, and non-technical unless otherwise justified.

2. Appearance of Facilities and People — The general public will usually form some impression of an organization based on the appearance of its facilities and its people. A favorable impression is easily generated if buildings and grounds are maintained in a neat and clean manner. Similarly, if employees are neat and professional in appearance and behavior, a positive impression is made.

3. Relations with Other Departments or Agencies — Internal conflicts ultimately become external conflicts if they are allowed to persist. A good manager will endeavor to create a sound and trusting relationship with other departments or groups within his or her organization. The public will feel more confident toward and have respect for an organization that demonstrates teamwork. Bickering between factions will generate negative impressions. An on-going effort should be made to have good working relationships with all local, state or federal agencies. Public demonstrations of such relationships should be made when appropriate.

4. Public Information Methods — Public information should be dispensed through such methods as news releases, public presentations, facility tours, and annual reports. A good manager will maintain contacts with local and state media outlets as a means of enhancing the disbursements of news releases. In making public presentations, a good manager will utilize personnel that are suited to public speaking and will strive to present the material in an interesting format using visual aids, charts, photographs, models, etc. Facility tours should be available to the public. Special provisions should be made to school children as a means of educating them and the public about a facility. An annual report should include both written and oral presentations.

5. Participation in Awards Programs — State and federal agencies as well as professional and technical associations frequently acknowledge excellence in wastewater operations with the presentation of awards. Unless there are special circumstances which would justify a different course of action, a treatment facility should always participate in such programs as a nominee or recipient when the opportunity arises. As a general rule, such opportunities do not present themselves unless a facility is doing a good job. Therefore, it makes good sense to use such an opportunity to enhance public relations by participating and generating appropriate publicity.

A program of developing and maintaining good public relations does not require a lot of complicated effort; but it does require a constant on-going effort. Organizations that genuinely care about the quality of their work and strive for excellence are inevitably the same ones that have sound public relations.

Revised
1/30/2012

Mississippi
Department of Environmental Quality
Wastewater Certification
*Need to Know Criteria **

CODE	CATEGORY	CLASS I	CLASS II	CLASS III	CLASS IV
CH 1	**MATHEMATICS**				
01	GENERAL	A	P	P	P
02	CONVERSIONS	A	P	P	P
03	AREA/VOLUME/FLOW	A	P	P	P
04	DETENTION TIME	A	P	P	P
05	POUNDS	A	P	P	P
06	HEAD (TDH)	A	P	P	P
07	PUMP CAPACITY (GPM)	A	P	P	P
08	PERCENT REMOVAL	A	A	A	A
09	POPULATION EQUIVALENTS	A	P	P	P
	HYDRAULIC	A	P	P	P
	ORGANIC	A	A	P	P
10	CHLORINE DEMAND	A	A	P	P
11	ORGANIC LOADING (LAGOONS)	A	A	P	P
12	HYDRAULIC LOADING (SAND FILTERS)	A	A	P	P
13	BOD		A	P	P
14	SOLIDS (TSS,VSS)		A	P	P
15	FECAL COLIFORM		A	P	P
16	BACK-IN POUNDS		A	P	P
17	AIR SUPPLY (AERATED LAGOON)		A	P	P
18	SLUDGE VOLUME INDEX (SVI)		A	P	P
19	F/M RATIO		A	P	P
20	SLUDGE AGE (S.A.)			P	P
21	SURFACE LOADING RATE (SLR)			P	P
22	WEIR OVERFLOW RATE (WOR)			P	P
23	SOLIDS LOADING RATE			P	P
24	ORGANIC LOADING (AS,TF)			P	P
25	HYDRAULIC LOADING (TF)			A	A
26	RECIRCULATION (RATIO, RATE)			A	A
27	MIXING			A	A
28	SLUDGE PUMPING			A	P
29	DRYING BEDS			A	P
30	RETURN SLUDGE (MLSS METHOD)			A	P
31	WASTE SLUDGE (MLSS METHOD)			A	P
32	AIR SUPPLY (ACTIVATED SLUDGE)			A	A
33	MCRT				A
34	GAS PRODUCTION				A
35	MLSS CONCENTRATION (S.A., F/M)				A

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CODE	CATEGORY	CLASS I	II	III	IV
	MATHEMATICS CONT'D				
36	WASTE SLUDGE (MCRT METHOD)				P
37	MIXING (ALGEBRAIC)				P
CH 2	**WASTEWATER CHARACTERISTICS**				
01	TERMINOLOGY	K	K	C	C
02	PHYSICAL	K	K	C	C
03	CHEMICAL	K	K	C	C
04	BIOLOGICAL	K	K	C	C
05	SEWAGE QUANTITIES	K	K	C	C
CH 3	**PRE-TREATMENT**				
01	GENERAL	K	K	C	C
02	SCREENING	K	K	C	C
03	COMMUNITION	K	K	C	C
04	GRIT REMOVAL		K	C	C
05	OIL & GREASE REMOVAL	K	K	C	C
06	PRE-AERATION		K	C	C
07	FLOCCULATION			C	C
08	NEUTRALIZATION	K	K	C	C
09	CHLORINATION			C	C
10	FLOW EQUALIZATION			C	C
11	SEWER USE ORDINANCE	K	K	C	C
12	INDUSTRIAL WASTEWATER	K	K	C	C
CH 4	**PRIMARY TREATMENT**				
01	GENERAL		K	C	C
02	SEDIMENTATION		K	C	C
03	SKIMMING			C	C
04	CLARIFIERS		K	C	C
05	COMMON OPERATIONAL PROBLEMS			C	C
06	LABORATORY CONTROLS			C	C
CH 5	**BIOLOGICAL TREATMENT**				
01	BASIC CONCEPTS	C	C	C	C
02	MICROORGANISMS	K	K	C	C
03	CONVENTIONAL LAGOONS	C	C	C	C
04	AERATED LAGOONS	C	C	C	C
05	ANAEROBIC LAGOONS	K	C	C	C
06	TRICKLING FILTERS		K	C	C

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CODE	CATEGORY	CLASS I	CLASS II	CLASS III	CLASS IV
	BIOLOGICAL TREATMENT CONT'D				
07	ROTATING BIOLOGICAL CONTACTORS			C	C
08	ACTIVATED SLUDGE		C	C	C
09	SEQUENCING BATCH REACTORS			C	C
10	GENERAL FACILITY O & M	C	C	C	C
CH 6	**ADVANCED TREATMENT**				
01	DEFINITIONS/ GENERAL			K	K
02	BASIC NITROGEN REMOVAL			C	A
03	ADVANCED NITROGEN REMOVAL			C	A
04	BASIC PHOSPHORUS REMOVAL			K	C
05	ADVANCED PHOSPHORUS REMOVAL			K	C
06	PHYSICAL/ CHEMICAL TREATMENT			K	C
CH 7	**DISINFECTION**				
01	GENERAL	C	K	K	K
02	ALTERNATIVE DISINFECTANTS	K	K	C	C
03	CHLORINATION/ DECHLORINATION	C	C	C	C
04	ULTRAVIOLET IRRADIATION	K	K	C	C
05	OZONATION	K	K	C	C
CH 8	**SLUDGE TREATMENT AND DISPOSAL**				
01	GENERAL		C	C	C
02	SOURCES/ CHARACTERISTICS			C	C
03	SLUDGE THICKENING		C	C	C
04	SLUDGE STABILIZATION **			C	C
05	SLUDGE CONDITIONING		C	C	C
06	SLUDGE DEWATERING **		C	C	C
07	FINAL DISPOSAL **		K	C	C
CH 9	**FLOW MEASUREMENT**				
01	HISTORICAL BACKGROUND	C	C	C	C
02	GENERAL	C	C	C	C
03	WEIRS	C	C	C	C
04	FLUMES	K	C	C	C
05	METERS & RECORDERS	K	C	C	C

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Mississippi
Department of Environmental Quality
Wastewater Certification
Need to Know Criteria *

CODE	CATEGORY	CLASS I	CLASS II	CLASS III	CLASS IV
CH 10	**COLLECTION SYSTEMS**				
01	HISTORICAL BACKGROUND	K	K	C	C
02	GENERAL/ DEFINITIONS	K	K	C	C
03	CONSTRUCTION	K	K	C	C
04	DESIGN FACTORS	K	K	C	C
05	INFILTRATION/ INFLOW	K	K	C	C
06	O & M	K	K	C	C
07	PUMPING STATIONS	K	K	C	C
CH 11	**PUMPING**				
01	GENERAL	K	K	C	C
02	TYPES OF PUMPS	K	K	C	C
03	PUMP STATIONS	K	K	C	C
04	ANALYSIS **	K	K	C	C
05	O & M	K	K	C	C
CH 12	**RECORDS & REPORTS**				
01	GENERAL	C	C	C	C
02	PHYSICAL	C	C	C	C
03	OPERATIONAL	C	C	C	C
04	MAINTENANCE	C	C	C	C
05	PERSONNEL	C	C	C	C
06	BUDGET & COSTS	C	C	C	C
CH 13	**SAFETY**				
01	GENERAL	C	C	C	C
02	PRACTICES	C	C	C	C
03	EQUIPMENT & SUPPLIES	C	C	C	C
04	RESCUE PRACTICES	C	C	C	C
CH 14	**LABORATORY**				
01	PURPOSE	K	K	C	P
02	PROCEDURES	K	K	C	P
03	GLASSWARE	K	K	C	P
04	WEIGHTS	K	K	C	C
05	SAMPLING	K	K	C	C
06	GENERAL	K	K	C	C
07	SAFETY	K	K	C	C

Revised
1/30/2012

Mississippi
Department of Environmental Quality
Wastewater Certification
*Need to Know Criteria **

CODE	CATEGORY	CLASS I	CLASS II	CLASS III	CLASS IV
	LABORATORY CONT'D				
08	ANALYSES	K	K	C	C
09	SUMMARY	K	K	C	C
CH 15	**FACILITIES MANAGEMENT ****				
01	BASIC PRINCIPLES	K	K	C	C
02	PERSONNEL	K	K	C	C
03	PLANNING	K	K	C	C
04	REGULATIONS	K	K	C	C
05	FINANCES	K	C	C	C
06	OPERATION AND MAINTENANCE	C	C	C	C
07	SAFETY AND HEALTH	C	C	C	C
08	EMERGENCY PREPAREDNESS/ RESPONSE	K	C	C	C
09	PUBLIC RELATIONS	K	C	C	C

* SOURCE: MISSISSIPPI WASTEWATER FACILITIES OPERATIONS/TRAINING MANUAL 5th Edition

** DEPTH OF KNOWLEDGE IN THESE CATEGORIES INCREASES WITH HIGHER CLASSES

K = KNOWLEDGE (List, Identify)
C = COMPREHENSION (Explain, Define)
A = APPLICATION (Routine Situations)
P = PROBLEM SOLVING (Non-Routine Situations)

Revised April 13, 2009

MDEQ CONVERSION FACTORS

MULTIPLY	BY	TO OBTAIN
Cubic Feet	7.5	Gallons
Cubic Feet/Second	0.646	Million Gallons/Day
M.G.D.	1.55	C.F.S.
Cubic Feet Water	62.4	Pounds
Gallons	8.34	Pounds
Gallons	0.133	Cubic Feet
Feet of Water	0.44	Lbs/Sq. Inch
Lbs/Sq. Inch	2.3	Feet of Water
Pounds of Water	0.016	Cubic Feet
Degrees Centigrade	9/5 C + 32	Degrees Fahrenheit
Degrees Fahrenheit	5/9 (F-32)	Degrees Centigrade
Acres	43,560	Square Feet
Cubic Yards	27	Cubic Feet
Horsepower	33,000	Ft.Lbs/Min
Horsepower	550	Ft.Lbs/Second
Horsepower	746	Watts
Horsepower	0.746	Kilowatts
Gallons	231	Cubic Inches
Pounds of Water	0.1198	Gallons
Population	0.17	Pounds/Day BOD
Population	100	Gallons/Day
TO OBTAIN	**BY**	**DIVIDE**

Revised April 13, 2009

WASTEWATER FORMULAS

1. Circumference of a Circle = 2 (R or (DUse Pi (( ) = 3.14

2. See Conversion Sheet

3. Area: Rectangle or Square:

   $A = L \times W$

   Circle:

   $A = (R^2$ or $\frac{(D^2}{4}$

   Volume = Area x Depth

   Flow (Q) = V x A (where V = velocity in ft/sec)

4. Detention Time = $\frac{\text{Volume}}{\text{Flow}}$

5. Lbs = MG x 8.34 x mg/l

   Lbs/Day = MGD x 8.34 x mg/l

6. Total Dynamic Head (TDH) = Static Head + Friction Head + Station Head

   Static Head = Final Elevation - Wet Well Elevation
   Friction Head = Friction Loss x Length of Pipe
   Station Head = Head Loss through fittings, valves, etc. (Given)

7. Pump Capacity or Drawdown(GPM)

   Small Station Drawdown (stop inflow) = $\frac{\text{Volume Wet Well (Gals.)}}{\text{Pump Run Time (Mins.)}}$

   Large Station Drawdown (continuous inflow) = Pump Rate + Fill Rate

8. Percent Removal = $\frac{\text{Influent - Effluent}}{\text{Influent}} \times 100$

9. Hydraulic P. E. = $\frac{\text{Gallons/Day}}{100}$

   Organic P. E. = $\frac{\text{Lbs BOD/Day}}{0.17}$

10. Chlorine Demand = Chlorine Dosage - Chlorine Residual

11. Organic Loading (Lagoon) = $\frac{\text{BOD applied (lbs/Day)}}{\text{Water Surface Area (acres)}}$

12. Hydraulic Loading (Sand Filters) = $\dfrac{\text{Total Flow to Filter (GPD)}}{\text{Surface Area of Filter (SF)}}$

13. BOD_5 = [Initial D. O. - Final D. O.] x $\dfrac{\text{300 ml}}{\text{ml sample}}$

14. TSS = [W_2 - W_1] x $\dfrac{1{,}000{,}000}{\text{ml sample}}$ Where: W_1 = weight of filter in grams (Tare Weight)
W_2 = weight of filter and residue in grams (Gross Weight)
W_3 = weight of filter and ash in grams (Ash Weight)

VSS = [W_2 - W_3] x $\dfrac{1{,}000{,}000}{\text{ml sample}}$

15. Fecal Coliform Count = Number of Colonies x $\dfrac{100}{\text{ml sample}}$

16. Back-In Pounds = See Lbs Formula, #5

17. Aerated Lagoon O_2 Required (Lbs/Day) = BOD Loading (Lbs/Day) x % Removal x 1.5

Aerator Run Time (Hrs/Day) = $\dfrac{O_2 \text{ Required (Lbs/Day)}}{\text{Aerator HP x Aeration capacity (Lbs/HP/Hr)}}$

18. Sludge Volume Index (SVI) = $\dfrac{\text{Volume (ml/l) settled sludge @ 30 min.}}{\text{MLSS (mg/l)}}$ x 1000

19. Sludge Age = $\dfrac{\text{MLSS in aeration tank (Lbs)}}{\text{TSS entering aeration tank (Lbs/Day)}}$

20. F/M Ratio = $\dfrac{\text{BOD entering aeration tank (Lbs/Day)}}{\text{MLVSS in aeration tank (Lbs)}}$

21. Surface Loading Rate = $\dfrac{\text{Flow applied (gpd)}}{\text{Surface Area (SF)}}$

22. Weir Overflow Rate = $\dfrac{\text{Flow applied (gpd)}}{\text{Length of weir (Ft)}}$

23. Solids Loading Rate = $\dfrac{\text{MLSS applied (Lbs/Day)}}{\text{Surface Area (SF)}}$

24. Organic Loading (AS) = $\dfrac{\text{BOD applied (Lbs/Day)}}{\text{Volume of A.T. (1000 CF)}}$

Organic Loading (TF) = $\dfrac{\text{BOD applied (Lbs/Day)}}{\text{Volume of Filter Media (1000 CF)}}$

25. Hydraulic Loading (TF) = $\dfrac{\text{Total Flow to Filter (GPD)}}{\text{Surface Area of Media (SF)}}$

26. Recirculation Ratio (TF) = $\dfrac{\text{Recirculated Flow}}{\text{Raw Wastewater Flow}}$

Recirculation Rate (TF) = Recirculation Ratio x Raw Wastewater Flow

27. Mixing: $C_T = \dfrac{(C_1 \times Q_1) + (C_2 \times Q_2)}{Q_T}$

28. Sludge Pumping: Lbs/Day Wasted = MGD x 8.34 x mg/l wasted

29. Drying Bed Volume (CF) = Area of Bed (SF) x Depth (Ft)

30. Return Sludge

MLSS method: $\%RS = \dfrac{\text{MLSS (mg/l)}}{\text{RS (mg/l)} - \text{MLSS (mg/l)}} \times 100$

Return Sludge Rate = % Return Sludge x Raw Wastewater Flow

31. Waste Sludge:

MLSS Method: $MG = \dfrac{[\text{Actual MLSS} - \text{Desired MLSS}]\text{ (mg/l)} \times \text{A.T. Volume (MG)}}{\text{SS in Waste Sludge (mg/l)}}$

32. Air Supply (CF/Lb BOD destroyed) $= \dfrac{\text{Total CF air supplied}}{\text{Lbs/Day BOD destroyed}}$

33. Mean Cell Residence Time (MCRT) $= \dfrac{\text{MLSS (Lbs) in A.T.} + \text{MLSS (lbs) in Clarifier}}{\text{SS Wasted (Lbs/Day)} + \text{Effluent SS (Lbs/Day)}}$

34. Daily Gas Production (CF/Day) = Volatile solids destroyed (Lbs/Day) x Gas Production Rate (CF/Lb VS destroyed)

35. MLSS Concentration: Calculate MLSS concentration from given F/M or SA (#19, #20)

36. Waste Sludge:

MCRT Method

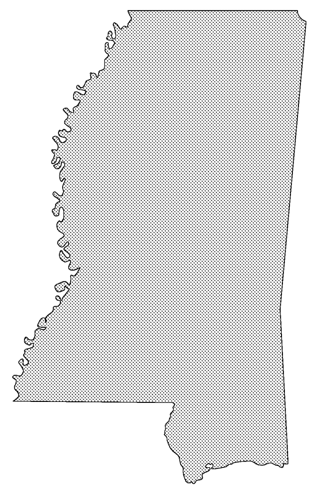
$\text{Lbs/Day} = \dfrac{\text{MLSS in A.T. \& Clarifier (Lbs)} - \text{Effluent SS (Lbs/Day)}}{\text{Desired MCRT (Days)}}$

$\text{MGD} = \dfrac{\text{Waste Sludge (Lbs/Day)}}{\text{SS in Waste Sludge (mg/l)} \times 8.34}$

$\text{MGD} = \dfrac{\text{Waste Sludge (MG)} \times \text{24 Hrs/Day}}{\text{Wasting Period (Hrs)}}$

37. Solve for unknown using Mixing Formula (# 27)

Regulations
For the Certification of
Municipal and Domestic Wastewater
Facility Operators



STATE OF MISSISSIPPI

MISSISSIPPI DEPARTMENT OF ENVIRONMENTAL QUALITY
OFFICE OF POLLUTION CONTROL
P.O. BOX 10385
JACKSON, MISSISSIPPI 39289-0385

Adopted January 28, 1987

Revised April 28, 1994
Revised January 28, 1999
Revised February 28, 2002
Revised August 26, 2004

SECTION 1. GENERAL

(1) These regulations are promulgated under the authority provided by Miss. Code Ann. Section 21-27-207.

(2) Miss. Code Ann. Section 21-27-211 requires that beginning on July 1, 1987, all municipal and domestic wastewater treatment plants be operated by persons who are certified as qualified to operate such facilities.

(3) Certificates shall be valid for three (3) years, unless revoked or invalidated for cause.

(4) In the event of temporary loss of an operator, notice shall be immediately given to the Department and the continued operation of such facility without a certified operator may proceed on an interim basis for a period not to exceed one hundred eighty (180) days, except for good cause shown upon petition to the Department.

(5) These regulations do not pertain to a wastewater treatment facility treating wastewater generated solely by an industry and owned and operated by said industry.

SECTION 2. DEFINITIONS

(1) "Association" means the Mississippi Water and Pollution Control Operator's Association.

(2) "Certificate," the certification of competency issued by the Department stating that the operator has met the requirements for the specified operator classification.

(3) "Commission," the Mississippi Commission on Environmental Quality.

(4) "Community water system" means any water system serving piped water for human consumption to fifteen (15) or more individual service connections used year-round by consumers or regularly serving twenty-five (25) or more individual consumers year-round, including, but not by way of limitation, any collection, pretreatment, treatment, storage and/or distribution facilities or equipment used primarily as part of, or in connection with, such system, regardless of whether or not such components are under the ownership or control of the operator of such system.

(5) “Department,” the Mississippi Department of Environmental Quality.

(6) “Experience,” means direct observation of and/or participation in the operation and maintenance of a wastewater facility, including, but not limited to, process control activities, facility maintenance, record keeping and NPDES monitoring activities. Experience requirements must be in accordance with the facility minimum visitation schedule as outlined in Section 5, Operator Responsibilities.

(7) "Operator," the person who directly supervises and is personally responsible for the daily operation and maintenance of a wastewater facility, community water system or commercial nonhazardous solid waste management landfill.

(8) "Person," the state or other agency or institution thereof, any municipality, political subdivision, public or private corporation, individual, partnership, association or other entity, and includes any officer or governing or managing body of any municipality, political subdivision, or public or private corporation, or the United States or any officer or employee thereof.

(9) "Pollution," the contamination or other alteration of the physical, chemical or biological properties of any waters of the state, including change in temperature, taste, color, turbidity, or odor of the waters, or the discharge of any liquid, gaseous, solid, radioactive or other substance or heat into any waters of the State.

(10) “Professional Reference,” a person (other than a relative or a subordinate) who is familiar with the applicant’s experience working in a wastewater facility.

(11) "Wastewater Facilities," the pipelines or conduits, pumping stations, force mains, treatment plants, lagoons or any other structure, device, appurtenance or facility, whether operated individually or in any combination, used for collecting, treating and/or disposing of municipal or domestic wastewater, by either surface or underground methods, which is required to have a permit under the provisions of Miss. Code Ann. Section 49-17-29.

(12) "Waters of the state," the waters within the jurisdiction of this state, including all streams, lakes, ponds, impounding reservoirs, marshes, watercourses, waterways, wells, springs, irrigation systems, drainage systems and all other bodies or accumulations of water, surface and underground, natural or artificial, situated wholly or partly within or bordering upon the state, and such coastal waters as are within the jurisdiction of the state, except lakes, ponds or other surface waters which are wholly landlocked and privately owned.

SECTION 3. CLASSIFICATION OF WASTEWATER FACILITIES

(1) Wastewater facilities shall be classified in accordance with criteria outlined below. The facility operator must be certified at a level equivalent to or higher than the facility classification.

CLASS	FACILITY	DESIGN CAPACITY
I-C	Collection only (voluntary)	up to 1,000,000 GPD (1.0 MGD)
II-C	Collection only (voluntary)	greater than 1,000,000 GPD (1.0 MGD)
I	Waste Stabilization Lagoon	All
	Septic Tank-Sand Filter	All
II	Aerated Lagoon	All
	Trickling Filter	less than 300,000 GPD (0.3 MGD)
	Activated Sludge	less than 100,000 GPD (0.1 MGD)
III	Trickling Filter	300,000 to 3,000,000 GPD (0.3 to 3.0 MGD)
	Activated Sludge	100,000 to 2,000,000 GPD (0.1 to 2.0 MGD)
IV	Trickling Filter	greater than 3,000,000 GPD (3.0 MGD)
	Activated Sludge	greater than 2,000,000 GPD (2.0 MGD)

(2) Special cases which do not fall within the guidelines shall be considered on an individual basis and classified by the Department.

SECTION 4. CERTIFICATION REQUIREMENTS

(1) Operator Qualifications for Certification

(a) Class IV

1. The applicant must have at least a bachelor's degree in engineering, biological sciences, mathematics, chemistry, or physics from an accredited college or university, at least one (1) year of experience in a Class IV wastewater facility, pass the required written examination and submit two (2) professional references, or

2. The applicant must be a graduate of an accredited high school, or equivalent (GED) have at least six (6) years experience in a Class IV or Class III wastewater facility, of which one (1) year must be in a Class IV plant, pass the required examination and submit two (2) professional references.

(b) Class III

1. The applicant must have graduated from an accredited high school, or equivalent (GED) , have at least three (3) years of experience in a Class IV, III, or II wastewater facility, of which one (1) year must be in a Class IV or Class III plant, pass the required written examination and submit two (2) professional references, or

2. The applicant must have a minimum of six (6) years experience in a Class IV, III, or II wastewater facility, of which one (1) year must be in a Class IV or Class III plant, pass the required written examination and submit two (2) professional references.

(c) Class II

1. The applicant must have graduated from an accredited high school, or equivalent (GED) , have at least one (1) year of experience in a Class IV, III, or II wastewater facility, pass the required written examination and submit one (1) professional reference, or

2. The applicant must have a minimum of three (3) years experience in a wastewater facility, of which one (1) year must be in a Class IV, III, or II plant, pass the required written examination and submit one (1) professional reference.

(d) Class I

The applicant must have at least one (1) year of experience in a wastewater facility, pass the required written examination and submit one (1) professional reference.

(e) Class I-C

The applicant must have at least one (1) year experience working in a collection system, pass the required written examination and submit one (1) professional reference.

(f) Class II-C

1. The applicant must have graduated from an accredited high school, or equivalent (GED), have at least two (2) years experience working in a collection system, of which one (1) year must be in a Class II-C system, pass the required written examination and submit two (2) professional references, or

2. The applicant must have four (4) years experience working in a collection system, one (1) year of which must be in a Class II-C system, pass the required written examination and submit two (2) professional references.

(g) Operators who have completed college courses, short courses, correspondence courses, etc., may be given credit for any deficiency in their experience and/or education, except that such courses cannot be substituted for one (1) year of wastewater facility experience. The Department shall award credit for experience using the following criteria:

1. Eight (8) weeks of classroom instruction in the operation and maintenance of wastewater treatment facilities will be equivalent to one (1) year experience.

2. Four (4) weeks of Department or Association sponsored classroom instruction in the operation and maintenance of wastewater treatment facilities will be equivalent to one (1) year experience.

3. Each year of college completed in engineering, biological sciences, mathematics, chemistry, or physics will be considered the equivalent of two (2) years experience. Thirty (30) semester hours are equal to one (1) year of college.

4. Special education, training, or experience which does not fall within these guidelines shall be considered in individual cases by the Department.

(2) Professional References

Persons who are familiar with the applicant’s experience working in a wastewater facility must complete professional reference forms provided by the Department . These forms must be submitted with the certification application.

(3) Application

(a) An operator desiring to be certified shall file an application with the Department on a form provided by the Department.

(b) The Department shall review applications and supporting documents and experience of the applicant, determine the eligibility of the applicant, and issue certificates when the applicant meets the requirements of the Municipal and Domestic Water and Wastewater System and Nonhazardous Solid Waste Management Facilities Operator's Certification Act of 1992 and these regulations.

(c) The Commission may deny an application if the Commission determines that the applicant has not complied with all of the provisions of these regulations and with all other applicable Federal, State and local statutes and regulations or has submitted inaccurate or false information in the application, or has submitted incomplete application forms after being notified in writing by the Department that the application is incomplete. The Commission shall make determinations regarding issuance or denial of the certificate based upon the information contained in the application, the applicant’s actions during any prior term of certification, and any other pertinent information that is available to the Commission.

(4) Examinations

(a) The Department shall prepare written examinations to be used in determining knowledge, ability, and judgment of the operators.

(b) Examinations shall be held at places and times set by the Department.

(c) A fee, to be set by the Commission, will be charged for the examination.

(d) An operator who passes an examination must be certified within three (3) years following the date the examination was taken. Otherwise, the operator will be required to take another written examination in order to be certified.

(e) An operator who fails to pass an examination may repeat the examination at the next regularly scheduled examination.

(f) Examination papers will not be returned to the operator.

(g) An operator who fails to pass an examination may review his paper by submitting a written request to the Department within thirty (30) days following notification of the examination grade.

(h) No operator shall be allowed to sit for a Class III or Class IV examination without proof of having taken and passed a Class II examination.

(5) Reciprocity

(1) An applicant may be certified without examination provided that the individual has passed the appropriate class Association of Boards of Certification (ABC) examination or any state's (or other certifying authority's) examination that has been approved as equivalent by ABC.

(2) Applicants for certification through reciprocity must meet the education and experience requirements for the class certificate requested as previously described.

(6) Certification Fees

(a) A fee to be set by the Commission shall be charged for certification and renewal in any classification and must accompany the application for certification or renewal.

(b) Fees from applicants who are not certified will be returned.

SECTION 5. OPERATOR RESPONSIBILITIES

(1) Certified operators in charge of wastewater facilities must personally visit said facilities at a sufficient frequency and duration to perform such tasks as may be required by the permit and to ensure proper operation and management of said wastewater facilities. Unless otherwise stated in the facility's permit or an order of the Commission, certified operators in charge of wastewater facilities shall visit the facilities, as a minimum, according to the following schedule:

Class I Facility	One (1) day per week
Class II Facility	Two (2) days per week
Class III Facility	Three (3) days per week
Class IV Facility	Five (5) days per week

(2) Certified operators in charge of wastewater facilities shall be thoroughly familiar with all monitoring and reporting requirements mandated by the facility's permit and shall ensure said facility complies with these requirements.

(3) Certified operators in charge of wastewater facilities must maintain written documentation of each facility visit. Documentation of facility visits shall be made available to the Department upon request.

SECTION 6. RENEWAL OF CERTIFICATES

(1) Subject to the provisions of Section 5 (2), certificates may be renewed without examination, however, in order to be eligible for certificate renewal, a certification renewal application should be filed prior to the expiration of the existing certificate. The application must be accompanied by the renewal fee and also proof of completing the continuing education requirements found in paragraph (3). Additionally, an operator, if practicing, must have demonstrated competency. Certified operators who file renewal applications more than sixty (60) days after the expiration of their certificate will be required to pass the written exam in order to be eligible for certification.

(2) Notwithstanding the provisions of Section 5 (1), any wastewater facility operator who holds a restricted certificate (i.e., valid only for a particular facility and/or class of facilities) may obtain a renewal certificate with identical restrictions provided that all conditions of paragraph (1) are satisfied.

(3) Continuing education

(a) Operators must receive thirty six (36) hours of related continuing education during the three (3) year period for which their certification is valid. A minimum of eighteen (18) of this thirty six (36) hours must be satisfied by attending Department sponsored training.

(b) Certified collection system operators must receive eighteen (18) hours of related continuing education during the three (3) year period that their certification is valid.

(c) Operators who have been certified for three (3) consecutive three (3) year periods, must receive twenty four (24) hours of continuing education during the fourth and subsequent three (3) year periods for which their certificate is valid. A minimum of twelve (12) hours must be satisfied by attending Department sponsored training. or Association sponsored Short Courses.

(d) Exceptions to the twenty four (24) hours of Department sponsored training requirement may be considered by the Department in individual cases, such as operators who possess valid Mississippi Certificates and are employed and reside outside the state of Mississippi, provided they submit proof of attendance of equivalent training.

(e) Continuing education credit will be given as follows:

1. Attending one (1) day of Department sponsored training will be equivalent to six (6) hours of continuing education.

2. Attending one (1) Association sponsored week long wastewater treatment short course will be equivalent to thirty two (32) hours of Department sponsored continuing education.

3. Association sponsored wastewater continuing education short courses will be evaluated, upon request, based on technical content, and Department sponsored continuing education credit will be awarded for actual hours attended.

4. Certified Operators who serve as instructors/presenters at Association sponsored training sessions shall receive two (2) hours of continuing education for each hour of actual presentation time.

5. Attending one (1) Association monthly District meeting will be equivalent of to one (1) hour of continuing education. Association District meetings and/or training sessions held other than on a monthly basis, will be evaluated, upon request, based on technical content, and continuing education credit will be awarded for actual hours attended.

6. Association annual conferences will be evaluated, upon request, based on technical content, and Department sponsored continuing education credit will be awarded for actual hours attended.

7. Organizations that provide technical training, including, but not limited to, the Mississippi Water Environment Association and the Mississippi Rural Water Association may request Department approval of training for continuing education credit. The Department shall consider requests for Department sponsored continuing education credit for training in which the Department staff actively participate in the continuing education curriculum development, presentation and evaluation.

8. Special schools, experience, training, correspondence courses, and/or other education and/or experiences may be approved at the discretion of the Department.

SECTION 7. REVOCATION OR SUSPENSION OF CERTIFICATES

(1) The Commission may revoke or suspend the certificate of an operator, following a hearing before the Commission, when it is found that the operator:

(a) has practiced fraud or deception,
(b) fails to use reasonable care, judgment, and/or apply knowledge in the performance of duties,
(c) is incompetent or unable to properly perform duties,
(d) knowingly submits false or inaccurate information for issuance or renewal of a certificate under these regulations,
(e) willfully fails to comply with the conditions of the certificate issued by the Commission, or
(f) violates any provision of these regulations, the Municipal and Domestic Water and Wastewater System and Nonhazardous Solid Waste Management Facilities Operator's Certification Act of 1992, or any applicable rule, regulation or written order of the Commission.

(2) In the event the Commission suspends the certificate of an operator, the Commission may, as a part of the suspension, require the operator to comply with all applicable laws and regulations, to obtain additional continuing education and/or to complete other actions as required by the Commission. Failure to comply with the terms of the suspension may result in revocation of the operator’s certificate.

SECTION 8. ENFORCEMENT AND APPEALS

Enforcement and appeals shall be in accordance with the Municipal and Domestic Water and Wastewater System and Nonhazardous Solid Waste Management Facilities Operator's Certification Act of 1992.

LIST

OF

REFERENCES

LIST OF REFERENCES

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GLOSSARY

OF

TERMS

A

ABSORPTION	The taking up of one substance into the body of another.
ACRE-FOOT	A volume of water 1 foot deep and 1 acre in area, or 43,560 cubic feet.
ACTIVATED SLUDGE	Sludge floc produced in raw or settled wastewater by the growth of organisms (including zoogleal bacteria) in the presence of dissolved oxygen. The term "activated" comes from the fact that the sludge is teaming with active, or living, micro-organisms.
ACTIVATED SLUDGE PROCESS	A biological wastewater treatment process in which a mixture of wastewater and activated sludge is agitated and aerated. The activated sludge is subsequently separated from the treated wastewater (mixed liquor) by sedimentation, and wasted or returned to the process as needed.
ADSORPTION	The adherence of a gas, liquid, or dissolved material on the surface of a solid.
ADVANCED TREATMENT	See tertiary treatment.
AERATE	To impregnate a liquid with air.
AERATED POND	A wastewater treatment pond in which mechanical or diffused-air aeration is used to supplement the oxygen supply.
AERATION	The bringing about of intimate contact between air and a liquid by one or more methods, such as spraying the liquid in the air, bubbling air through the liquid, or agitation of the liquid to promote surface absorption of the air.
AERATION PERIOD	(1) The theoretical time, usually expressed in hours, during which mixed liquor is subjected to aeration in an aeration tank while undergoing activated sludge treatment; it is equal to the volume of the tank divided by the volumetric rate of flow of the wastewater and return sludge; (2) The theoretical time that water is subjected to aeration.
AERATOR	A device that promotes aeration.
AEROBIC	(1) A condition in which "free" or dissolved oxygen (0_2) is present; (2) Requiring, or not destroyed by, the presence of free oxygen.
AGITATOR	Mechanical apparatus for mixing and/or aerating; a device for creating turbulence.
AIRBOUND	Obstructed, as to the free flow of water, because of air entrapped in a high point; used to describe a pipeline or pump in such condition.
AIR GAP	In plumbing, the unobstructed vertical distance through the free atmosphere between the lowest opening from any pipe or faucet supplying water to a tank or plumbing fixture and the flood-level rim of the receptacle.
AIRLIFT	A device for raising liquid by injection of air in and near the bottom of a riser pipe submerged in the liquid to be raised.

ALGAE — Primitive protists, one or many-celled, usually aquatic and capable of synthesizing their foodstuffs from carbon dioxide and water by photosynthesis.

ALKALINE — The condition of wastewater containing sufficient amounts of substances to raise the pH above 7.0.

ALUM — A common name for commercial grade aluminum sulfate, $Al(SO_4)_3$ x H_2O.

AMMONIA NITROGEN — A chemical combination of hydrogen (H) and Nitrogen (N) occurring extensively in nature; NH_3 and $NH4^+$.

ANAEROBIC — (1) A condition in which "free" or dissolved oxygen (O_2) is not present; (2) Requiring, or not destroyed by, the absence of free oxygen.

B

BACKFLOW — (1) A flow condition, induced by a differential in pressure, that causes the flow of water or other liquid into the distribution pipes of a potable water supply from any source or sources other than its intended source; (2) The backing up of water through a conduit or channel in the direction opposite to normal flow.

BACKFLOW PREVENTER — Any effective device, method, or construction used to prevent backflow into a potable water system.

BACKSIPHONAGE — A form of backflow caused by a negative or subatmospheric pressure within a water system.

BACTERIA — A group of universally distributed, rigid, essentially unicellular microscopic organisms lacking chlorophyll. Bacteria usually appear as spheroid, rod-like, or curved entities, but occasionally appear as sheets, chains, or branched filaments. Bacteria are usually regarded as protists.

BACTERIA, AEROBIC — Bacteria that require free elemental oxygen for their growth.

BACTERIA, ANAEROBIC — Bacteria that do not require free elemental oxygen for their growth.

BACTERIA, COLIFORM — A group of bacteria, predominantly inhabitants of the GROUP intestine of man or animals but also found on vegetation including all aerobic and facultative anaerobic gram-negative, nonspore-forming bacilli that ferment lactose with gas formation.

BACTERIA COUNT — A measure of the concentration of bacteria.

BACTERIA, FACULTATIVE — Bacteria that can adapt themselves to growth in the presence, as well as in the absence, of oxygen.

BACTERIA, PARASITIC — Bacteria that thrive on other living organisms.

BACTERIA, PATHOGENIC — Bacteria that may cause disease in the host organism by their parasitic growth.

BACTERIA PLATE COUNT — Number of colonies of bacteria grown on selected solid media at a given temperature and incubation period, usually expressed as the number of bacteria per milliliter of sample.

BASIN	A shallow depression or tank through which liquid may be passed or in which it is detained for treatment or storage.
BIOCHEMICAL	Pertaining to chemical change resulting from biological action. Measured by or expressed in the terms of the ensuing chemical change.
BIOCHEMICAL ACTION	Chemical changes resulting from the metabolism of living organisms.
BIOCHEMICAL OXYGEN DEMAND (BOD)	A measurement of the amount of oxygen required by the micro-organisms to metabolize or digest the organic material in the wastewater.
BIOCHEMICAL OXYGEN DEMAND, STANDARD	Biochemical oxygen demand as determined under standard laboratory procedure for 5 days at 20˚C, usually expressed in milligrams per liter.
BIOLOGICAL OXIDATION	The process whereby living organisms in the presence of oxygen convert the organic matter contained in wastewater into a more stable or mineral form.
BIOLOGICAL WASTE-WATER TREATMENT	Forms of wastewater treatment in which bacterial or biochemical action is intensified to stabilize the unstable organic matter present and remove non-settling solids.
BURNER, WASTE GAS	A device used for burning the waste gas from an anaerobic sludge-digestion tank.
BY-PASS	An arrangement of pipe, conduits, gates, and valves whereby the flow may be passed around a hydraulic structure or appurtenance.

C

CAVITATION	The action resulting when a liquid passes through a region of very low pressure to a region of higher pressure. Dissolved gases and/or liquid vapor come out of solution in the low pressure region and form bubbles. The bubbles suddenly collapse in the region of higher pressure, their contents go back in solution, and the liquid filling the voids left by the bubbles acquires a high velocity and frequently will dig pits in nearby metal surfaces, for example, pump impeller, trailing surfaces, and venturi exit cones. Vibration may also occur.
CENTRIFUGAL PUMP	A pump consisting of an impeller fixed on a rotating shaft and enclosed in a casing and having an inlet and a discharge connection. The rotating impeller creates pressure in the liquid by the velocity derived from centrifugal force.
CHAMBER	A general term applied to a space enclosed by walls and a floor or a compartment, often prefixed by a descriptive word, such as “grit chamber”, “flushing chamber”, indicating its function.
CHEMICAL OXYGEN DEMAND (COD)	A measure of the oxygen-consuming capacity of inorganic and organic matter present in wastewater. It is expressed as the amount of oxygen consumed from a chemical oxidation in a specific test.
CHLORINATION	The application of chlorine to wastewater, generally for the purpose of disinfection.
CHLORINATION, BREAKPOINT	The addition of chlorine to wastewater until the chlorine demand has been satisfied and further additions result in a residual that is directly proportioned to the amount added beyond the breakpoint.

CHLORINATION, POST	The application of chlorine to wastewater subsequent to any treatment step, including prechlorination. The term refers only to a relationship of the point of application and the treatment step.
CHLORINATION, PRE	The application of chlorine to wastewater before any treatment step. This term refers only to relationship of the point of application and the treatment step.
CHLORINE	An element ordinarily existing as a greenish yellow gas approximately 2.5 times as heavy as air. At atmospheric pressure and a temperature of -30.1˚F (-34.5˚C), the gas becomes an amber liquid about 1.5 times as heavy as water. The chemical symbol of chlorine is Cl, its atomic weight is 35.457, and its molecular weight is 70.914.
CHLORINE, AVAILABLE	A measure of the total oxidation power of chlorinated lime and hypochlorites.
CHLORINE CONTACT CHAMBER	A detention basin provided primarily to secure the diffusion of chlorine through the liquid. Also called chlorination chamber.
CHLORINE DEMAND	The difference between the amount of chlorine added to wastewater and the amount of residual chlorine remaining at the end of a specified contact time. The chlorine demand for given water varies with the amount of chlorine applied, time of contact, temperature, pH, and nature and the amount of impurities in the water.
CHLORINE, DOSE	The amount of chlorine applied to a liquid, usually expressed in milligrams per liter or pounds per million gallons.
CHLORINE, LIQUID	Elemental chlorine placed in a liquid state by a combination of compression and refrigeration of dry, purified chlorine gas. Liquid chlorine is shipped under pressure in steel containers.
CHLORINE, RESIDUAL	Chlorine (combined and free chlorine) remaining in wastewater at the end of a specific contact period.
CLARIFIER	See sedimentation tank.
COAGULATION	The destabilization and initial aggregation of colloidal and finely divided suspended matter by the addition of a floc-forming chemical or by biological processes.
COLIFORM GROUP	A group of bacteria that inhabit the intestinal tract of man, warm blooded animals and may be found in plants, soil and air and the aquatic environment.
COLLOIDS	Finely divided soils that will not settle but may be removed by coagulation, biochemical action, or membrane filtration.
COMBINED AVAILABLE RESIDUAL CHLORINE	That portion of the total residual chlorine remaining in wastewater at the end of a specified contact period that will react chemically and biologically as chloramines or organic chloramines.
COMBINED SEWER	A sewer intended to receive both wastewater and storm or surface water.
COMBINED WASTEWATER	A mixture of surface runoff and other wastewater such as domestic or industrial wastewater.

COMMINUTION	The process of cutting solids contained in wastewater flow before they enter the flow pumps or other units in a treatment plant.
COMMINUTOR	A grinder or shredder that converts bulky solid wastes into small particles.
COMPOSITE SAMPLES	Samples collected at regular intervals, sometimes in proportion to the existing flow, and then combined to form a sample representative of flow over a period of time.
CONCENTRATION	(1) The amount of a given substance dissolved or suspended in a unit volume of solution; (2) The process of increasing the solids per unit volume in a liquid.
CONDUIT	Any artificial or natural duct, either open or closed, for conveying liquids or other fluids.
CONTAMINATION	Any introduction into water of micro-organisms, chemicals, wastes, or wastewater in a concentration that makes the water unfit for its intended use.
CROSS-CONNECTION	(1) A physical connection through which a supply of potable water could be contaminated or polluted. (2) A connection between a supervised potable water supply and an unsupervised supply of unknown potability.

D

DECOMPOSITION	The breakdown of complex material into simpler substances by chemical or biological means.
DEGREASING	The process of removing greases and oils from waste, wastewater, sludge, or solid wastes.
DENITRIFICATION	The conversion of nitrate nitrogen (NO_3) to nitrogen gas (N_2).
DEOXYGENATION	The depletion of DO in a liquid either under natural conditions associated with the biochemical oxidation of organic matter present or by the addition of a chemical reducing agent.
DETENTION TIME	The theoretical time required to displace the contents of a tank or treatment unit at a given rate of discharge (volume divided by rate of discharge).
DIAPHRAGM PUMP	A pump in which a flexible diaphragm, generally of rubber or equally flexible material, is the principal feature. It is fastened at the edges in a vertical cylinder. When the diaphragm is raised, suction is exerted, and when it is depressed the liquid is forced through a discharge valve.
DIFFUSED AIR AERATION	The process by which air is compressed and discharged below the mixed liquor surface through some type of air diffusion device.
DIFFUSER	A porous plate, tube, or other device through which air is forced and divided into minute bubbles for diffusion in liquids. Commonly made of porous ceramic, metal, or plastic materials.
DIGESTER	A tank in which sludge is placed to permit digestion to occur. Also called sludge digestion tank.

DIGESTER COILS	A system of pipes for hot water or steam installed in a digestion tank to heat the digester contents.
DIGESTION	The biological decomposition of organic matter in sludge, resulting in partial gasification, liquefaction, and mineralization.
DISINFECTION	The process of killing the larger portion of micro-organisms in or on a substance with the probability that all the pathogenic bacteria are killed by the agent used.
DISSOLVED OXYGEN	Molecular or “free” oxygen (O_2) dissolved in water or (DO) wastewater.
DISSOLVED SOLIDS	Very small, non-settling particles defined by the method of measurement (See Standard Methods).
DISTRIBUTOR	A mechanical device used for spreading wastewater over the surface of a trickling filter. A rotary distributor is usually used.
DITCH, OXIDATION	A modification of the activated sludge process or the aerated pond, in which the mixture under treatment is circulated in an endless ditch and aeration and circulation are produced by a mechanical device.
DOMESTIC WASTEWATER	Wastewater derived principally from dwellings, business buildings, institutions and other non-industrial sources.

E

EFFLUENT	Wastewater or other liquid, partially or completely treated, or in its natural state, flowing out of a reservoir, basin, treatment plant, or industrial treatment plant.
EJECTOR, PNEUMATIC	A device for raising wastewater, sludge, or other liquid by entraining it in a high velocity stream of air or water.
ELUTRIATION	A process of sludge conditioning whereby the sludge is washed with either fresh water or plant effluent to reduce the demand for conditioning chemicals and to improve settling or filtering characteristics of the solids. Alkalinity is reduced in its process.
ENZYMES	Substances produced by living organisms that speed up chemical changes.
EVAPORATION	The process by which a liquid becomes a vapor at temperatures below the boiling point.

F

FACULTATIVE	Having the ability to live under both aerobic and anaerobic conditions.
FILAMENTOUS BACTERIA	Bacteria that grow in a thread or filamentous form.
FILTER	A device or structure for removing solid or colloidal material, usually of a type that cannot be removed by sedimentation. The liquid is passed through a filtering medium that may be natural or artificial granular material, finely woven cloth, unglazed porcelain, specially prepared paper, or synthetic media. There are many types of filters used in water or wastewater treatment.

FILTER FLOODING	The filling of a trickling filter to an elevation above the top of the media by closing all outlets, in order to control nuisance of filter flies.
FILTER, HIGH-RATE	A biological filter operated at a high average daily dosing rate usually between 10 to 40 MGD/ACRE including any recirculation of effluent.
FILTER, INTERMITTENT	A natural or artificial bed of sand or other fine-grained material to the surface of which wastewater is intermittently applied in flooding doses and through which the liquid portion passes. Solids are retained in the upper layers of the bed under aerobic conditions.
FILTER, LOW-RATE	A biological filter designed to receive a small load of BOD per unit volume of filtering material and to have a low dosage rate per unit of surface area, usually 1 to 4 MGD/ACRE, and generally without recirculation. Organic loading (BOD) rate is usually in the range of 5 to 25 lb/1,000 cu ft. Also called standard-rate filter.
FILTER MEDIA	(1) Any material through which wastewater is passed for the purpose of purification, treatment, or conditioning; (2) A cloth or metal material of some appropriate design used to intercept sludge solids in sludge filtration.
FILTER PONDING	The formation of ponds, as the filter pooling.
FILTER POOLING	The formation of pools of wastewater as a result of surface clogging of filters.
FILTER PRESS	A device operated mechanically for partially separating water from solid material.
FILTER, ROUGHING	A filter or relatively coarse material operated at a high rate as a preliminary treatment.
FILTER, SAND	A filter in which sand is used as filtering media.
FILTER, TRICKLING	A filter consisting of a bed of coarse material, such as broken stone, slate, slats, brush, or plastic materials, over which wastewater is distributed or applied in drops, films, or spray from troughs, drippers, moving distributors, or fixed nozzles and through which it trickles to the underdrains, giving opportunity for the formation of zoogleal slimes on the media surfaces to clarify and oxidize the wastewater.
FILTER, VACUUM	A filter consisting of a cylindrical drum mounted on a horizontal axis, covered with a filter cloth, revolving with a partial submergence in liquid. A vacuum is maintained under the cloth for the larger part of a revolution to extract moisture. The cake is then scraped off. Operation is continuous.
FILTRATE	The liquid that has passed through a filter.
FLOC	Small gelatinous masses formed in a liquid by agglomeration of smaller particles.
FLOCCULATION	In water and wastewater treatment, the agglomeration of colloidal and finely divided suspended matter after coagulation by gentle stirring by either mechanical or hydraulic means. In biological wastewater treatment in which coagulation is not used, agglomeration may be accomplished biologically.

FLOTATION	The rising of suspended matter to the surface of the liquid in a tank as scum - by aeration, evolution of gas, chemicals, electrolysis, heat, or bacterial decomposition - and the subsequent removal of the scum by skimming.
FLUME	An open conduit constructed on a grade of wood, masonry, metal, or synthetic materials.
FOOD/MICRO-ORGANISM RATIO	An aeration tank loading parameter. Food may be expressed in pounds of COD or BOD added per day to the aeration tank, and micro-organisms are expressed as MLVSS in the aeration tank.
FREEBOARD	The vertical distance between the normal maximum level of the surface of the liquid in a conduit, reservoir, or tank or canal and the top of the side-walls of an open conduit, basin, the top of a dam, or the top of a levee. The discharge is provided so that waves and other movement of the liquid will not overtop the confining structure.

G

GASIFICATION	The transformation of soluble and suspended organic materials into gas during waste decomposition.
GATE	A movable, watertight barrier for the control of liquid in a waterway.
GATE, SLUICE	A gate used for controlling the flow of water. It is constructed to slide vertically, and fastened into or against the walls of dams, tanks, conduits, or other structures.
GO-DEVIL	A scraper with self-adjusting spring blades, inserted in a pipe line, and carried forward by the fluid pressure for clearing away deposits and roots.
GRAB SAMPLE	A single sample not necessarily taken at a set time or flow. An instantaneous sample.
GREASE	A group of substances including fats, waxes, free fatty acids, calcium and magnesium soaps, mineral oils, and certain other nonfatty materials.
GREASE SKIMMER	A device for removing floating grease or scum from the surface of wastewater.
GRIT	The heavy suspended mineral matter in wastewater, such as sand, gravel, and cinders.
GRIT COLLECTOR	A device placed in a grit chamber to convey deposited grit to a point of collection.
GROUNDWATER	Subsurface water occupying the zone of saturation, from which wells and springs are fed. In a strict sense, the term applies only to water below the water table.

H

HEAD	A term used in expressing the pressure or energy of fluids in terms of the height of a vertical column of water.

HEAD LOSS	Energy lost, expressed in head, from flowing fluids due to friction and turbulence.
HEAVY METALS	Metals that can be precipitated by hydrogen sulfide in acid solution, for example, lead, silver, gold, mercury, bismuth, and copper.
HYDRATED LIME	Limestone that has been "burned" and treated with water under controlled conditions until the calcium oxide portion has been converted to calcium hydroxide.
HYDRAULIC DENTENTION TIME	The theoretical time required to displace the contents of a tank or unit at a given discharge rate (volume of tank divided by discharging rate).
HYDRAULIC LOADING	The volume of wastewater applied to a unit in a given time.
HYDRAULICS	The branch of science or of engineering dealing with water or other fluid in motion.
HYDROCARBONS	Compounds that consist solely of carbon and hydrogen.

I

IMHOFF CONE	A conically shaped one-liter graduated glass vessel used to measure the approximate volume of settleable solids in various liquids of wastewater origin during various settling periods.
IMPELLER	A set of vanes designed to rotate and to cause rotation of a mass of fluid.
INCINERATION	The combustion (by burning) of organic matter in wastewater sludge solids after water evaporation from the solids.
INDUSTRIAL WASTES	The solid and liquid wastes from industrial processes, as distinct from domestic or sanitary wastes.
INDUSTRIAL WASTE-WATER	Wastewater in which industrial wastes predominate.
INFILTRATION	(1) The groundwater that leaks into a pipe through joints, porous walls, or breaks; (2) The entrance of groundwater into a gallery.
INFLOW	Usually the rainfall that enters a sewer system through direct connections such as roof leaders and catch basins.
INFLUENT	Wastewater or other liquid, raw or partially treated, flowing into a reservoir, basin, treatment process, or treatment plant.
INORGANIC MATTER	Chemical substances of mineral origin.
INORGANIC WASTE	Waste material such as sand, salt, iron, calcium, and other mineral materials which are not converted in large quantities by micro-organism action.

L

LAGOON	A pond containing raw or partially treated wastewater in which aerobic or anaerobic stabilization occurs.

LAGOON, SLUDGE	A basin used for the storage, digestion, or dewatering of sludge.
LIME	Any of a family of chemicals consisting essentially of calcium hydroxide or calcium oxide.
LIQUOR	Water, wastewater, or any combination; commonly used to designate liquid phase when other phases are present.
LIQUOR, MIXED	A mixture of activated sludge and wastewater into which oxygen or air is added in the activated sludge process.
LIQUOR, SUPERNATANT	(1) The liquor overlying deposited solids; (2) The liquid in a sludge digestion tank that lies between the sludge at the bottom and the floating scum at the top.

M

MANOMETER	An instrument, usually a V-shaped tube, for measuring pressure.
MATTER	Solids, liquids, and gases.
MATTER, INORGANIC	Chemical substances of mineral origin.
MATTER, ORGANIC	Chemical substances of animal or vegetable origin, or more correctly, of basically carbon structure. They include most carbon compounds; most are combustible and many are volatile.
MATTER, SUSPENDED	Solids in suspension in wastewater or effluent; also called suspended solids, SS.
MECHANICAL AERATION	A class of processes by which the surface of an aeration tank is mechanically agitated to cause spray or wave resulting in aeration of the liquid.
MICRO-ORGANISMS	Microscopic objects which require energy, carbon, and small amounts of inorganic elements to grow and multiply. They get these requirements from the wastewater and the sun and in doing so help to remove the pollutants from the wastewater.
MICRON SCREENING	A form of fine screening using woven fabrics mounted on the periphery of a revolving drum.
MILLIGRAMS PER LITER (mg/l)	A unit of concentration on weight/volume basis, milligrams per liter. Equivalent to ppm when speaking of water or wastewater.
MIXED LIQUOR	Used to refer to the mixture of wastewater and return activated sludge in the aeration tank of an activated sludge system.
MOST PROBABLE NUMBER (MPN)	That number of organisms per unit volume that, in accordance with statistical theory, would be more likely than any other number to yield the observed test result or that would yield the observed test result with the greatest frequency. Expressed as density of organisms per 100 milliliters. Results are computed from the number of positive findings of coliform group organisms resulting from multiple-portion decimal-dilution plantings.

N

NITRIFICATION	The conversion of nitrogenous matter into nitrates by bacteria.
NOTCH	The opening in a dam, spillway, or measuring weir for the passage of water.
NOZZLE	(1) A short, cone-shaped tube used in an outlet for a hose or pipe. The velocity of the merging stream of water is increased by the reduction in cross-sectional area of the nozzle; (2) A short piece of pipe with a flange on one end and a saddle flange on the other end; (3) A side outlet attached to a pipe by means such as riveting, brazing, or welding.
NUTRIENTS	Substances involved in energy transfer and necessary for the growth and development of plants and animals.

O

ODOR CONTROL	The prevention or reduction of objectionable odors by chlorination, aeration, or other processes.
ORGANIC LOADING	Pounds of BOD,COD,TOC, or TOD applied per day to a unit process.
ORGANIC NITROGEN	Nitrogen combined in organic molecules such as proteins, amines, and amino acids.
ORGANIC WASTE	Waste material which comes from animal or vegetable sources. Organic waste generally can be consumed by bacteria and other small organisms. Organic wastes contain mainly carbon and hydrogen along with other elements.
OUTFALL	The point, location, or structure where wastewater or drainage discharges from a sewer, drain, or conduit into the receiving waters.
OVERAERATED	Sludge which has long periods in the aeration tanks with dissolved oxygen concentration of 4 mg/l and above.
OVERFLOW RATE	One of the criteria for the design of sedimentation tanks in treatment plants; the rate of flow per surface area of settling tank.
OXIDATION	The addition of oxygen to a compound. More generally, any reaction that involves the loss of electrons from an atom.
OXIDATION POND	Preferred term is stabilization lagoon.
OXYGEN	An element with chemical symbol O, atomic weight 8, and molecular weight 16.
OXYGEN, AVAILABLE	The quantity of DO available for the oxidation or organic matter in a water body.
OXYGEN BALANCE	The relation between the BOD of a wastewater or treatment plant effluent and the oxygen available in the diluting water.
OXYGEN CONSUMED	A measure of the oxygen-consuming capability of inorganic and organic matter present in wastewater.

OXYGEN DEFICIENCY	(1) The additional quantity of oxygen required to satisfy the oxygen requirement in a given liquid. Usually expressed in milligrams per liter; (2) Any atmosphere containing less than 13 percent oxygen is dangerous to human beings and is called an atmosphere with oxygen deficiency.
OXYGEN, DISSOLVED	The oxygen dissolved in a liquid, usually expressed (DO) either in milligrams per liter or percentage of saturation.
OXYGEN UPTAKE RATE	The amount of oxygen being used by an activated sludge system during a septic period of time.

P

PARSHALL FLUME	A device which measures the critical depth to determine flow.
PARTS PER MILLION (PPM)	The number of weight or volume units of a minor constituent present with each 1 mil units of the major constituent of a solution or mixture. Formerly used to express the results of most water and wastewater analyses, but more recently replaced by the ratio milligrams per liter (to which it is essentially equivalent).
PEAK LOAD	The maximum rate of flow to a wastewater treatment plant.
PERCOLATION	The flow or trickling of a liquid through a contact or filtering medium.
pH	A symbol denoting the negative logarithm of the hydrogen ion concentration in a solution. pH values run from 1 to 14. The number 7 indicates neutrality.
PHOSPHORUS	A highly reactive nonmetallic element, found in wastewater in three principal forms: orthophosphate ion, polyphosphates, and organic phosphorous compounds.
PHOTOSYNTHESIS	A process in which chlorophyll containing plants produce complex organic (living) materials from carbon dioxide, water and inorganic salts, with sunlight as the source of energy. Oxygen is produced in this process as a waste product.
PIN FLOC	Very fine floc particles with poor settling characteristics.
POLLUTION, WATER	A condition created by the presence of harmful or objectionable material in water.
POLLUTION LOAD	(1) The quantity of material in a waste stream that requires treatment or exerts an adverse effect on the receiving system; (2) The quantity of material carried in a body of water that exerts a detrimental effect on some subsequent use of that water.
POPULATION EQUIVALENT	The calculated population which would normally contribute the same amount of biochemical oxygen demand as the wastewater. A common base is 0.17 lbs of 5-day BOD per capita per day.
PONDING	The formation of pools or ponds of wastewater as a result of surface clogging in trickling filters.
POTABLE WATER	Water that does not contain objectionable pollution, contamination, minerals, or

	infective agents and is considered satisfactory for domestic consumption.
PREAERATION	A preparatory treatment of wastewater consisting of aeration to remove gases, add oxygen, or promote flotation of grease and aid coagulation.
PRECIPITATION	The phenomenon that occurs when a substance held in solution in a liquid passes out of solution into a solid form.
PRECIPITATION, CHEMICAL	Precipitation induced by the addition of chemicals.
PRESSURE	In hydraulics, the total load or force acting on a surface per unit area or intensity of pressure above local atmospheric pressure.
PRESSURE, ATMOSPHERIC	The pressure exerted by the atmosphere at any point. Such pressure decreases as the elevation of the point above sea level increases. One atm is equal to 14.7 lb/sq in.; 29.92 in. or 760 mm of mercury column; or 33.90 ft of water column at average sea level under standard conditions.
PRESSURE, HYDROSTATIC	The pressure, expressed as a total quantity or per unit area, exerted by a body of water at rest.
PRESSURE, NEGATIVE	A pressure less than the local atmospheric pressure at a given point.
PRETREATMENT	The use of racks, screens, communitors, and grit removal devices to remove metal, rocks, sand, eggshells, and similar materials which may hinder the operation of a treatment plant.
PRIMARY TREATMENT	The first phase of wastewater treatment, consisting of separating the readily settleable or floatable solids by sedimentation and skimming.
PROCESS	A sequence of operations.
PUMP	A mechanical device for causing flow, raising or lifting water or other fluid, or applying pressure to fluids.
PURIFICATION	The removal, by natural or artificial methods, of objectionable matter from wastewater.
PUTREFACTION	Biological decomposition of organic matter with the production of ill-smelling products associated with anaerobic conditions.

R

RATE, FILTRATION	The rate of application of wastewater to a filter, usually expressed in million gallons per acre per day or gallons per minute per square foot.
RATE, INFILTRATION	The rate at which groundwater enters a ditch, gallery, drain, sewer, or other underground conduit.
RATE, RECIRCULATION	The rate of return of part of the effluent from a treatment process to the incoming flow.
REAERATION, SLUDGE	The continuous aeration of sludge after its initial aeration for the purpose of

	improving or maintaining its condition.
RECIRCULATION	The return of process effluent to the incoming flow.
RIP RAP	Broken stone or boulders placed compactly or irregularly on dams, levees, dikes, or similar embankments for protection or earth surfaces against the action of waves or current.
RISING SLUDGE	A problem in secondary settling tanks generally attributed to denitrification in the sludge blanket.
ROTARY DISTRIBUTOR	A movable distributor made up of horizontal arms that extend to the edge of the circular filter bed, revolve about a central post, and distribute liquid over the bed through holes or jets in the arms.
ROTATING BIOLOGICAL REACTOR	A rotating bed of synthetic media that moves through a fixed trough into which wastewater is fed. The media is partially submerged in the wastewater, giving opportunity for the formation of zoogleal slimes on the media surfaces to clarify and oxidize the wastewater.

S

SANITARY SEWER SYSTEM	A sewer intended to carry wastewater from homes, businesses, and industries.
SCREENING	The removal of relatively coarse SS and floating solids by straining through racks or screens.
SCUM	(1) The layer or film of extraneous or foreign matter that rises to the surface of a liquid and is formed there; (2) A residue deposited on a container at the water surface; (3) A mass of matter that floats on the surface of wastewater.
SECONDARY TREATMENT	Phase of wastewater treatment in which dissolved or suspended material is converted into a form more readily separated from the wastewater.
SEDIMENT	Solid material settled from suspension in a liquid.
SEDIMENTATION	The process of settling by gravity of suspended matter.
SELF-PURIFICATION	The natural processes occurring in a stream or other body of water that result in the reduction of bacteria, satisfaction of the BOD, stabilization of organic constituents, replacement of depleted DO, and the recovery of the stream biota.
SEPTIC	The condition produced by the growth of anaerobic organisms. If severe, the wastewater turns black, giving off foul odors and creating a heavy oxygen demand.
SEWAGE	Preferred term is wastewater.
SEWER	A pipe or conduit that carries wastewater or drainage water.
SEWER GAS	(1) Gas evolved in sewers that results from the decomposition of organic matter

	in wastewater; (2) Any gas present in the wastewater system, even though it is from such sources as gas main, gasoline, and cleaning fluids.
SHORT-CIRCUITING	The hydraulic conditions in a tank, chamber or basin where time of passage is less than that of the normal flow-through period.
SHREDDER, SCREENINGS	A device that chops up screenings.
SKIMMING	The process of removing floating grease or scum from the surface of wastewater in a tank.
SLIMES	Substances of viscous organic nature, usually formed from micro-biological growth.
SLOUGHINGS	Biological filter slimes that have been washed off the filter media.
SLUDGE	(1) The accumulated solids separated from wastewater during processing, or deposits on bottoms of streams or other bodies of water. (2) The precipitate resulting from chemical treatment, coagulation, or sedimentation of wastewater.
SLUDGE, ACTIVATED	Biological floc produced in raw or settled wastewater by the growth of zoogleal bacteria and other organisms in the presence of DO and accumulated in sufficient concentration by returning floc previously formed.
SLUDGE AGE	In the activated sludge process, a measure of the length of time a particle of SS is retained in the treatment process, expressed in days.
SLUDGE BED	An area comprising natural or artificial layers of porous material on which digested sludge is dried by drainage and evaporation. A sludge bed may be open to the atmosphere or covered, usually with a greenhouse-type superstructure.
SLUDGE BLANKET	A layer of sludge suspended within an enclosed body of wastewater, such as a settling tank.
SLUDGE BULKING	A phenomenon that occurs in activated sludge plants by which the sludge occupies excessive volumes and will not concentrate readily.
SLUDGE CONDITIONING	Treatment of liquid sludge to facilitate dewatering and enhance drainability
SLUDGE DENSITY INDEX (SDI)	The reciprocal of the SVI multiplied by 100.
SLUDGE DEWATERING	The process of removing a part of the water in sludge by any method, with or without heat, to form a semisolid mass or "cake".
SLUDGE DIGESTION	The process by which organic or volatile matter in sludge is gasified, liquefied, mineralized, or converted into more stable organic matter, through the activities of either anaerobic or aerobic organisms.
SLUDGE, RAW	Settled sludge removed from sedimentation tanks. Frequently referred to as undigested sludge.
SLUDGE SEEDING	In biological treatment of wastewater and associated sludges, the inoculation of

	the unit process with biologically active sludge, resulting in acceleration of the initial stage of the process.
SLUDGE THICKENER	A tank or other equipment designed to concentrate wastewater sludge.
SLUDGE VOLUME INDEX (SVI)	A numerical expression of the settling characteristics of activated sludge. The ratio of the volume in milliliters of sludge settled from a 1,000-ml sample in 30 minutes to the concentration of mixed liquor in milligrams per liter multiplied by 1,000.
SOLIDS	Material in a solid state.
SOLIDS, COLLOIDAL	Finely divided solids intermediate between dissolved and suspended particles.
SOLIDS, DISSOLVED	Solids that are present in solution.
SOLIDS LOADING	The weight or mass of solids applied to a treatment process per unit time.
SOLIDS, NON- SETTLEABLE	Wastewater matter that will stay in suspension for an extended period of time.
SOLIDS, SETTLEABLE	(1) The matter in wastewater that will not stay in suspension during a preselected settling period, such as 1 hour, but either settles to the bottom or floats to the top; (2) In the Imhoff cone test, the volume of matter that settles to the bottom of the cone in 1 hour.
SOLIDS, SUSPENDED (SS)	Preferred term is matter, suspended. SS is an acceptable abbreviation, however.
SOLIDS, TOTAL (TS)	The sum of dissolved and undissolved constituents in wastewater, usually stated in milligrams per liter.
SOLIDS, VOLATILE	The quantity of solids in wastewater lost on ignition of (VS) the dry solids at 550˚C.
SOLUBLE	Capable of dissolving readily.
SPARGER	An air diffuser designed to give large bubbles, used singly or in combination with mechanical aeration devices.
SPECIFIC GRAVITY	The ratio of weight of a given volume of a substance to the weight of an equal volume of water.
STABILITY	The ability of any substance, such as wastewater, chemical, or digested sludge, to resist chemical or biological change.
STABILIZATION LAGOON	Any pond, natural or artificial, receiving raw or partially treated wastewater in which stabilization occurs because of sunlight, air, and micro-organisms.
“STANDARD METHODS”	Methods of analysis of water, wastewater, and sludge approved by the American Public Health Association, American Water Works Association, and the Water Pollution Control Federation.
STATOR	The stationary member of an electric generator, pump, or motor.
SUMP	(1) A tank or pit that receives drainage and stores it temporarily and from which the drainage is pumped or ejected; (2) A tank or pit that receives liquids.

SUPERNATANT	The liquid standing above a sediment or precipitate.

T

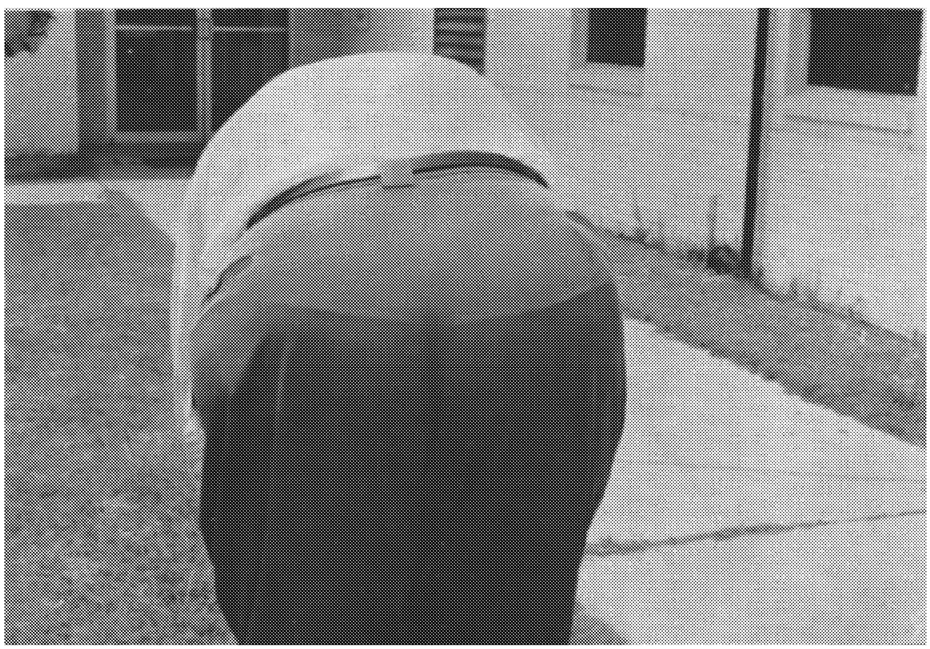
TANK	Any artificial receptacle through which liquids pass or in which they are held in reserve or detained for any purpose.
TERTIARY TREATMENT	Those processes that treat effluent from secondary treatment to remove or reduce nutrients, residual organics, and residual solids.
TOTAL ORGANIC CARBON (TOC)	A measure of the amount of carbon in a sample originating from organic matter only. The test is run by burning the sample and measuring the carbon dioxide produced.
TOXICITY	The ability of a waste to poison organisms.
TREATMENT	Any process involving the removal of solids or non-aqueous liquids from wastewater and/or transforming them into stable substances.
TREATMENT, PRELIMINARY	(1) The condition of a waste at its source before discharge to remove or neutralize substances injurious to sewers and treatment process or the effect a partial reduction in load on the treatment process: (2) In the treatment process, unit operations that prepare the liquor for subsequent major operations.
TREATMENT, PRIMARY	(1) The first major treatment in a wastewater treatment works; (2) The removal of a substantial amount of suspended matter but little or no colloidal and dissolved matter.
TREATMENT, SECONDARY	The processes that remove or reduce SS, DS, and fine and colloidal solids and cause the reduction of organic material.
TREATMENT, WASTEWATER	Any process to which wastewater is subjected to remove or alter its objectional constituents and thus render it less offensive or dangerous.
TRICKLING FILTER	A biological treatment process in which the wastewater trickles through a bed of slime-covered media and is treated by the action of the micro-organisms in the slime layer.
TRICKLING FILTER MEDIA	The solid material in a trickling filter which provides a surface for a biological film of micro-organisms. Crushed stone is the most commonly used media, but plastics are gaining popularity.
TURBIDITY	Cloudiness of wastewater due to suspended solids.

W

WASTE SLUDGE	That portion of settled solids from the final sedimentation unit that is removed from the wastewater treatment processes to the solids handling facilities for ultimate disposal.
WASTEWATER	The spent water of a community. From the standpoint of source, it may be a combination of the liquid and water-carried wastes from residences, commercial

buildings, industrial plants, and institutions, together with any groundwater, surface water, and storm water that may be present.

WASTEWATER, DOMESTIC	Wastewater derived principally from dwellings, office buildings, institutions, and the like. It may or may not contain groundwater, surface water, or storm water.
WASTEWATER FACILITIES	The structures, equipment, and processes that collect, carry away, and treat domestic and industrial wastes and dispose of the effluent.
WASTEWATER, SANITARY	(1) Domestic wastewater with storm and surface water excluded; (2) Wastewater discharging from the sanitary fixtures of dwellings (including apartment houses and hotels), office buildings, industrial plants, or institutions; (3) The water supply of a community after it has been used and discharged into a sewer.
WASTEWATER, STORM	The portion of liquid, resulting from precipitation runoff, flowing in combined sewers during or after a period of rainfall.
WASTEWATER TREATMENT WORKS	(1) An arrangement of devices and structures for treating wastewater, industrial wastes, and sludge; (2) A water pollution control plant.
WEIR	A device that has a crest and some side containment of known geometric shape, such as a V, trapezoid, or rectangle and is used to measure and/or control flow of liquids. The liquid surface is exposed to the atmosphere. Flow is related to upstream height of water above the crest, to position of crest with respect to downstream water surface, and to geometry of the weir opening.
WEIR LOADING	See overflow rate.
WET WELL	A compartment in which a liquid is collected and to which the suction pipe of a pump is connected.



THE END